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Tennessee Valley Authority, Chattanooga

Prepared for

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THE RELATIONSHIP OF URBAN RUNOFF TO LAND USE AND GROUNDWATER RESOURCES

Knoxville, Tennessee

1981-1982

Prepared by

Jack D. Milligan
I. Elaine Wallace
Roger P. Betson

Chattanooga, Tennessee

March 1984

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1. Introduction

In 1978 the Environmental Protection Agency (EPA) established the Nationwide Urban Runoff Program (NURP) for the purpose of determining the significance of urban runoff as a contributor to receiving water quality problems. The essence of this five-year program was the selection of 28 locations across the nation where the data gathering activities would take place. In the aggregate the data generated by the 28 NURP projects were to be evaluated by EPA in a national perspective, while the individual projects generally were to assess their data in terms of a local or regional perspective.

The 28 NURP projects were located in such a manner that the broad range of climatological, geological, and sociological areas of the nation were represented. The projects also contained common technical elements in order to provide a nationally comparable data base. Knoxville, Tennessee, was selected as one of the NURP studies because of its unique location within the ridge and valley province of the eastern United States and because it is characterized by extensive carbonate geology.

The Knoxville-Knox County Metropolitan Planning Commission (MPC) was the grantee of the partially EPA-funded NURP project in Knoxville, Tennessee. The Tennessee Valley Authority, through its Regional Water Management Program, enabled the MPC to obtain the EPA grant by providing a portion of the supplemental funding needed to meet EPA's matching funds requirement. The MPC was responsible for overall project management and administration, providing the local perspective in the assessment of the data base, and developing a public participation program. MPC contracted with the Tennessee Valley Authority (TVA) to conduct the data collection activities and supply MPC with this report and analysis of the data.

The data presented in this report includes quantity information on rainfall, runoff, and groundwater flow; and quality data on rainfall, dry precipitation, and stormwater runoff. Additionally, various statistical and numerical analysis of these data have been performed with the aim of providing a data base amenable to a local perspective interpretation. No attempt was made to evaluate alternative treatment techniques for urban runoff or their economics.

The Knoxville NURP project was conducted in two urban drainage systems within the confines of metropolitan Knoxville. These two drainage systems, First and Second Creeks, have been known for some time to be highly degraded, suspectedly from urban runoff. In a TVA report (Clark, et al., 1980), First and Second Creeks were classified as having critical stream problems which were impacting water quality in Fort Loudoun Reservoir along the Knoxville waterfront. Bacteriological contamination was known to be high in both streams, but it was unknown as to what other types and how much contamination existed in the streams. Biological surveys conducted by TVA in 1975 and 1980-81 on Second Creek found the aquatic communities therein to be depauperate, and dominated by a few tolerant species, which were indicative of an organically enriched environment.

The lower portion of Second Creek, near its confluence with Fort Loudoun Reservoir, was the site of the 1982 World's Fair. Original plans for the Fair called for the water of Second Creek to form a pool around which many of the Fair exhibits were to be constructed. However, the poor water quality in Second Creek precluded the implementation of this concept and the creek was ultimately routed under the pool through a concrete conveyance with treated public water used to maintain levels in the pool. Residual plans for the Fair site provide for a park and concession area with the pool as its centerpiece. It is not known whether Second Creek water will be used to maintain the pool. Hopefully, this report will provide information to aid in that decision.

II. Description of Study Area

A. Knox County

Location

Knox County, located in eastern Tennessee, lies wholly within the ridge and valley physiographic province of the southern Appalachian region, extending from 35°47'30" N. to 36°10'30" N. latitude and 83°39' W. to 84°16' W. longitude (figure II-1).

Geology

The topography of the county consists of alternating ridges and valleys which cut into the variably dipping, folded, and faulted sedimentary rocks (figure II-2). The rocks include limestone, dolomite, calcareous shale, sandstone, and sandy shale. The oldest rocks exposed are the Rome Formation of Early Cambrian age. These clastic rocks include sandstone and shale. Overlying the Rome Formation is a thick sequence of limestone, dolomite, and calcareous shale, ranging in age from Middle Cambrian to Middle Ordovician. The youngest rocks exposed are in the Clinch Sandstone of Early and Middle Silurian age atop House Mountain in the northeastern part of the county. Underlying the Clinch Sandstone is the Chickamauga group and Sequatchie Formation of Late Ordovician age, consisting of siltstone and shale. Underlying the Sequatchie Formation is the calcareous Chapman Ridge Sandstone of Middle and Late Ordovician age. Several belts of the Holston Formation, a red crystalline limestone of Middle to Late Ordovician age, strike northeast-southwest across the county.

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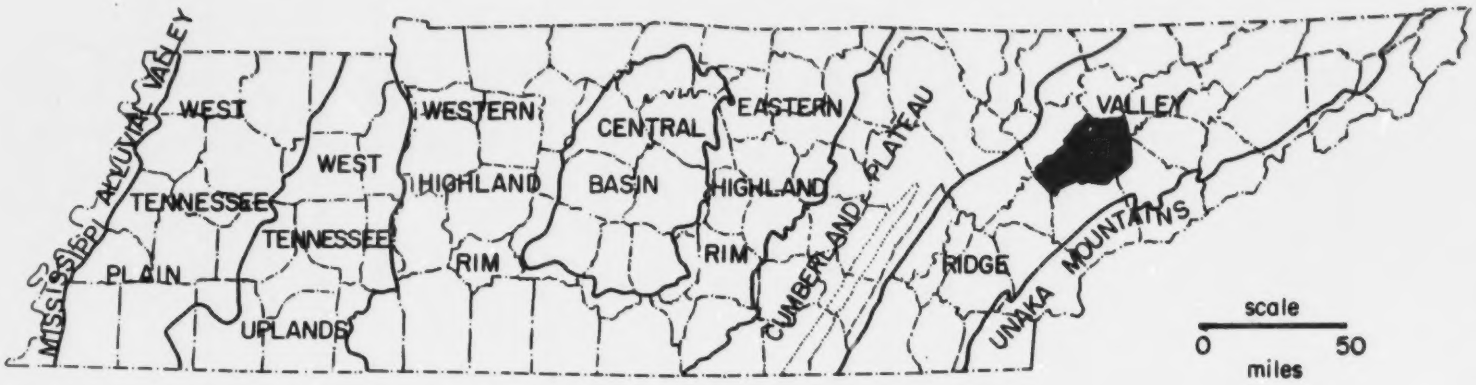
PHYSIOGRAPHIC PROVINCES IN TENNESSEE


MISSISSIPPI ALLUVIAL VALLEY
WEST
TENNESSEE
PLAIN
WEST
TENNESSEE
UPLANDS
WESTERN
HIGHLAND
RIM
CENTRAL
BASIN
EASTERN
HIGHLAND
RIM
CUMBERLAND PLATEAU
RIDGE
VALLEY
UNAKA MOUNTAINS
scale
0
50
miles

Physiographic provinces ir Tennessee.

SOURCE: Robert J. Floyd, Tennessee Rock and Mineral Resources, State of Tennessee, Department of Conservation, Division of Geology, Geology Bulletin 66, Nashville, Tennessee, 1966, p. 6.

FIGURE II-1.

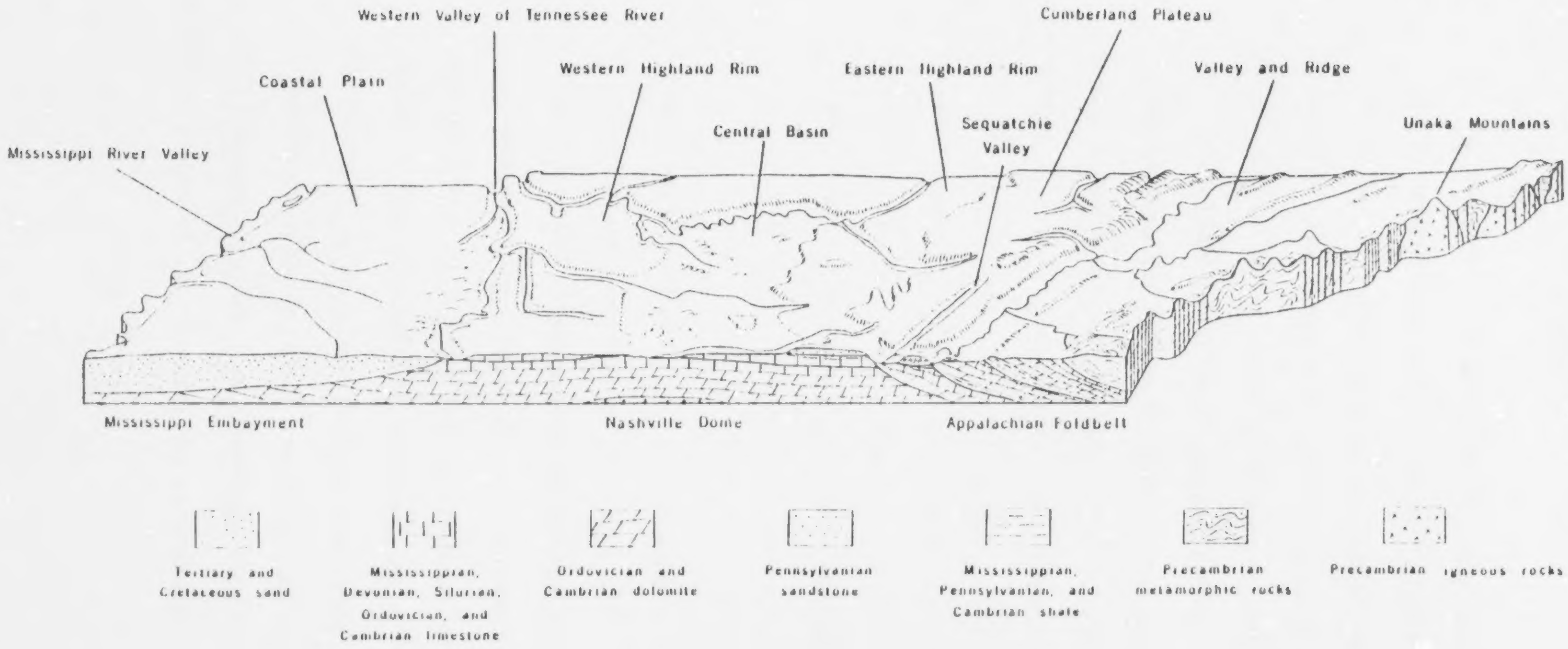

Western Valley of Tennessee River
Cumberland Plateau
Coastal Plain
Western Highland Rim
Eastern Highland Rim
Valley and Ridge
Central Basin
Sequatchie Valley
Unaka Mountains
Mississippi River Valley
Mississippi Embayment
Nashville Dome
Appalachian Foldbelt
Tertiary and Cretaceous sand
Mississippian, Devonian, Silurian, Ordovician, and Cambrian limestone
Ordovician and Cambrian dolomite
Pennsylvanian sandstone
Mississippian, Pennsylvanian, and Cambrian shale
Precambrian metamorphic rocks
Precambrian igneous rocks

Figure II-2 **Relief map of Tennessee showing the relationship of major geologic structures to physiographic units.**

Reproduced from best available copy.

Topography

Knox County, topographically, is included in the Open Hills surface type of the Appalachian Rough Lands Subdivision of the United States (Hammond 1964). In this surface type, 20 to 50 percent of the land is characterized by gentle slopes (less than 15 percent). More than 76 percent of these gentle slopes are in low-lands with local relief ranging from 300 to 500 feet. Differential weathering and erosion of folded and faulted sedimentary rocks of Cambrian to Silurian age have produced a series of subparallel ridges and valleys with an orientation of approximately N.55°E. to S.35°W. Relief between valley floors and ridge crests normally is between 180 and 400 feet, decreasing slightly from northeast to southwest across the county. County elevations range from 740 feet above sea level on the Clinch River to 2128 feet above sea level on House Mountain.

Soils

The differing soils of Knox County lie in several bands that transect the county in a northeast to southwest direction and relate to the outcrop of various rock strata. The predominant soil association in the county is Fullerton-Dewey-Dunmore-Sequoia. This association occupies a major part of the valleys of east Tennessee. It is developed on a surface that is mainly hilly. The soils, which are derived chiefly from limestone with narrower interbelts from shale, are highly variable in parent rock and depth; most have poor drainage. The crop productivity of most of the upland soils is moderate to low; the soils of the bottoms and terraces are more productive but limited in extent. These lowland soils, along with the better uplands, are well suited for farming. A large portion of the shallow, rocky, and steep soils can probably be best used for forests. Soils on uplands occupy about 76 percent of the county; those on alluvial foot slopes, 14 percent; those on stream terraces, 3 percent; and those on bottom lands, 7 percent.

Soil Texture--Most soils have textures ranging from loam to silty clay loam. Silt loams and silty clay loams predominate in the soils developed over limestone, loams, and clay loams in the Tellico-Neubert soil association, and fine sandy loams and clay loams in the Muskingum-Lehew soil association. Many of the soils on colluvium adjacent to the Muskingum-Lehew association are loam or fine sandy loam. A small amount of loamy fine sand is included with Staser fine sandy loam. The severely eroded Colbert and Talbott soils have a silty clay texture. Practically all the silty clay loam and clay loam soils are former areas of silt loams, respectively, that have lost through erosion either all or part of their original surface layers.

Soil Depth--The depth to bedrock ranges from zero to more than 20 feet. Fifty-seven percent of the county has a soil depth of more than five feet. These areas include the Decatur, Dewey, Fullerton, and Clarksville soils. The sequoia and Talbott soils, having depths ranging from about 18 inches to 5 feet, make up almost 14 percent of the county. The remaining 29 percent of the county is occupied mainly by soils having an average depth to bedrock of less than 20 inches; among these are the Dandridge, Litz, Montevallo, Carmuchee, Bland, Muskingum, and Lehew soils. These stony land types have an average depth to bedrock of less than 18 inches.

Climate

The study area is located in a broad valley between the Cumberland Mountains and the Great Smoky Mountains. These two mountain ranges have a significant influence upon the climate of the valley. Topography has a pronounced effect upon the prevailing wind direction. Winds usually have a southwesterly component during day time, while night time winds usually move from the northeast. The winds are relatively light and tornadoes are extremely rare.

Temperature--The average monthly temperature ranges from 39.4°F in January to 77.7°F in July, with an annual average of 58.9°F. July is usually the warmest month of the year, with July 1954 being the hottest month of record at an average temperature of 81.8°F. The highest temperature ever recorded, 104°F, occurred on July 12, 1930. The coldest weather usually occurs during the month of January, with the coldest month of record being January 1940, at an average temperature of 26.7°F. The lowest temperature of record is -16°F, occurring on January 6, 1884.

Precipitation--Rainfall is distributed throughout the year with a normal annual total of 47.98 inches (table II-1). The total rainfall amounts are greatest from midwinter to midsummer. Generally, winter storms are less intense, longer in duration,

Table II-1

Normal Monthly, Seasonal, and Annual Temperature and Precipitation of Knoxville, Tennessee

Month	Average temperature (°F)	Average precipitation (in.)	Driest (1952)	Wettest (1957)
December	40.7	4.44	3.99	5.16
January	39.4	4.66	4.56	9.63
February	41.8	4.66	2.11	7.86
Winter	40.6	13.76	10.66	22.65
March	49.4	5.16	3.87	2.26
April	58.8	4.18	1.12	4.56
May	67.3	3.76	3.32	3.53
Spring	58.5	13.10	6.31	10.35
June	74.8	4.07	1.98	5.86
July	77.7	4.54	2.64	0.70
August	76.7	3.73	4.57	4.07
Summer	76.4	12.34	9.19	10.63
September	71.5	2.81	1.94	6.98
October	59.9	2.63	0.63	3.43
November	48.2	3.34	5.27	7.45
Fall	59.9	8.78	7.84	17.86
Year	58.9	47.98	36.00	61.49

Note: McGhee Tyson Airport, 35°49'N., 83°59'W.
Elevation 980 feet

SOURCE: United States Weather Bureau, 1935-1974 and of greater total rainfall per event than summer storms. Approximately 12 inches of snow falls annually, and usually occurs in amounts of less than 4 inches at any one time. It is unusual for snow to remain on the ground in measureable amounts longer than one week and consequently mechanical and chemical snow removal is minimal.

Population

As shown in the following table, the population of Knox County has grown significantly in the past 15 years. Between 1960 and 1970 the population grew 10.3 percent, while between 1970 and 1975 it grew 9.8 percent. Between 1975 and 1990, the population is projected to grow an additional 23.7 percent.

Table II-2. Population Growth

Year	Population	Rate of Change (%)
1960[a]	250,523	
1970[b]	276,293	10.3
1975[c]	303,900	9.8
1980[c]	319,694	15.71
1990	376,900	23.7
1995	392,000	

---

a. U.S. Census of Population, 1960
b. U.S. Census of Population, 1970
c. U.S. Census of Population, 1980

Urban Drainage Areas

There are five drainage basins within the Knoxville-Knox County area which, by nature of their land use, may be considered urban. These include First Creek, Second Creek, Third Creek, Fourth Creek, and Ten Mile Creek. The two most intensely developed drainage basins, First Creek and Second Creek, were chosen for this study. In combination, these two creeks drain the entire Knoxville central business district in addition to substantial residential and commercial areas. A comprehensive analysis of these drainage basins was undertaken by Kung (Kung, 1980) in conjunction with a dissertation entitled *Geographic Aspects of the Urban Hydrology of Knoxville, Tennessee*, and much of the following information was obtained from that study.

B. First and Second Creek Basins

First Creek Drainage Basin--The First Creek drainage basin encompasses an area of 22.04 square miles, the largest in the city of Knoxville. Seventeen percent of the area (3.78 square miles) drains into sinkholes. These sinkhole areas are primarily in the north and northeast parts of the basin, as shown in figure II-3. The average drainage density of the First Creek basin is nine miles of channel per square mile, with the highest drainage density (13.4 mi/mi^2) on steep slopes and less soluble geologic formations, and lowest drainage density (4.8 mi/mi^2) on gentle slopes and more soluble rocks.

Elevations along Blackoak Ridge, the northern boundary of the basin, average about 1350 feet, with a maximum of 1410 feet just west of United States Highway 441. The crest of Sharp Ridge, across the center of the basin, is at about 1400 feet.

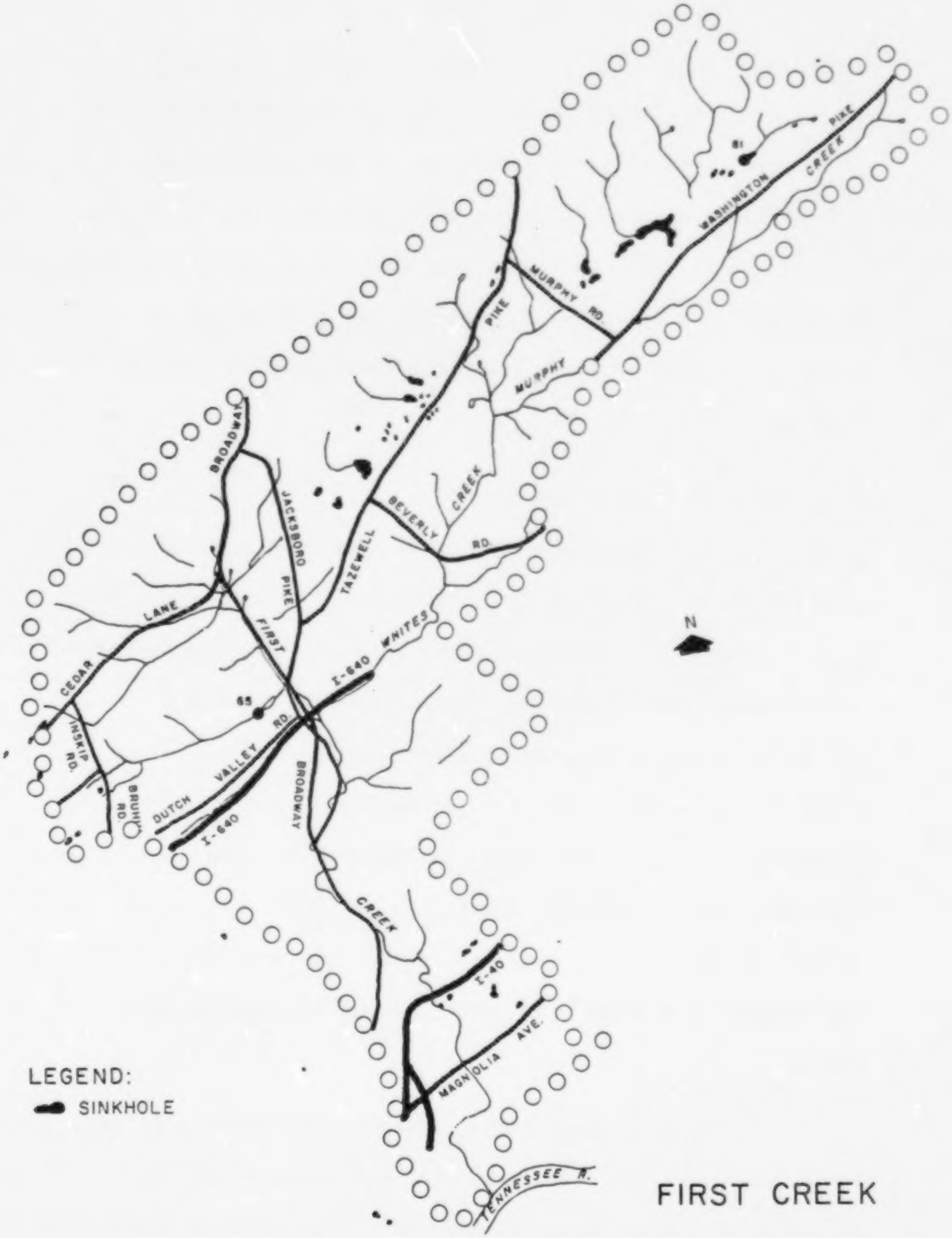

BROADWAY
JACKSBORO PIKE
TAZEWELL PIKE
MURPHY RD.
MURPHY
WASHINGTON PIKE
CREEK
BEVERLY RD.
CREEK
CEDAR LANE
FIRST
WHITES
I-640
INSKIP RD.
BRUHIN RD.
DUTCH VALLEY RD.
I-640
BROADWAY
CREEK
I-40
MAGNOLIA AVE.
TENNESSEE R.
65
81
N
LEGEND:
SINKHOLE
FIRST CREEK

FIGURE II - 3. SINKHOLE DISTRIBUTION

0 FEET 6000

The eastern end of the basin, near the head of Murphy Creek, has an elevation slightly above 1100 feet. The boundary between the First Creek and Second Creek basins ranges in elevation from 890 feet to 1400 feet, with the maximum of 1400 feet at Sharp Ridge. The lowest point of the basin, at the mouth of First Creek, on the Tennessee River, is at an elevation of 810 feet. The local relief, the difference between the highest and the lowest points of the basin, is 600 feet.

The geology in the basin is complex, with geologic formations ranging in age from early Cambrian (Rome Formation) to Middle Ordovician (Ottosee shale), and strike is in a northeast to southwest direction. Two thrust faults, comprising the Saltville Fault group, follow the north and south sides of Sharp Ridge. The Knoxville Fault crosses near Bethel and Vine Avenues. Blackoak Ridge is sustained by the Copper Ridge Dolomite, and Sharp Ridge is underlain by the Rome Formation (mostly sandstones) and Pumpkin Valley Shale. These formations are much less soluble and more resistant to erosion than some of the limestones and shales in the valley. The predominant joint systems are oriented northeast-southwest and northwest-southeast. In the ridge and valley province the joint pattern is generally closely related to the flow direction of surface and groundwater. A correlation exists among soil depth, soil permeability, and geology in the First Creek basin. Moderately deep and deep soils (greater than 4 feet) and moderate to high rates of soil permeability (greater than 0.6 inches per hour) are associated with carbonate rocks. Shallow soils (less than 4 feet) and less permeable soils (less than 0.6 inches per hour) predominate on the Ottosee and Pumpkin Valley Shales. Implications for basin hydrology are that direct surface runoff will occur more often in areas of shallow and less permeable soils and shale bedrocks and that more groundwater recharge will likely occur in areas of deep and permeable soils overlying carbonate rocks.

In the First Creek drainage basin, commercial land use is concentrated on the lower (downstream) portions of the basin and along Broadway (strip commercial development). Open and forest lands predominate in the northeastern portions of the basin. Although industrial and multifamily land uses cover small portions of the basin, single family residential land use is predominant.

Areas of potentially high water yield are associated with steep slopes, high elevations, shallow and less permeable soils (low soil moisture capacity), shale bedrock, faults acting as groundwater barriers, and densely developed residential and commercial land areas which have a large percentage of impervious surfaces. Areas of potentially low water yield are related to deep and more permeable soils, gentle slopes, and carbonate rocks where bypass losses of groundwater occur, especially in summer and fall when soil moisture is depleted. In general, low water yield occurs in summer and fall on relatively low elevations, deep and more permeable soils, carbonate rocks, and open and forested areas.

Second Creek Drainage Basin--The Second Creek watershed is adjoined on the east by the First Creek basin and on the west by the Third Creek basin. The Second Creek basin is elongated in shape and is the smallest major drainage basin in the Knoxville urban area. The creek originates on Blackoak Ridge north of Inskip and Norwood communities and drains into a gently rolling area. It has no major tributaries unlike the other principal streams in Knoxville. The creek flows into central Knoxville through the gap in Sharp Ridge where I-75, United States Highway 25W, and the Southern Railway pass through. Below the gap it passes the Southern Railway's Coster Yards and is repeatedly crossed by the railway before reaching downtown Knoxville. The creek enters the Tennessee River at the eastern edge of the campus of the University of Tennessee.

The basin has a drainage area of 7.1 square miles (4544 acres), including a scattered area of 0.5 square miles (320 acres) that drains into sinkholes. The complete drainage network is shown in figure II-4. Drainage density is high on steep slopes and high-elevation areas, while low drainage density is associated with gentle slopes and low-elevation areas such as the Coster railway yard. The highest drainage density occurs

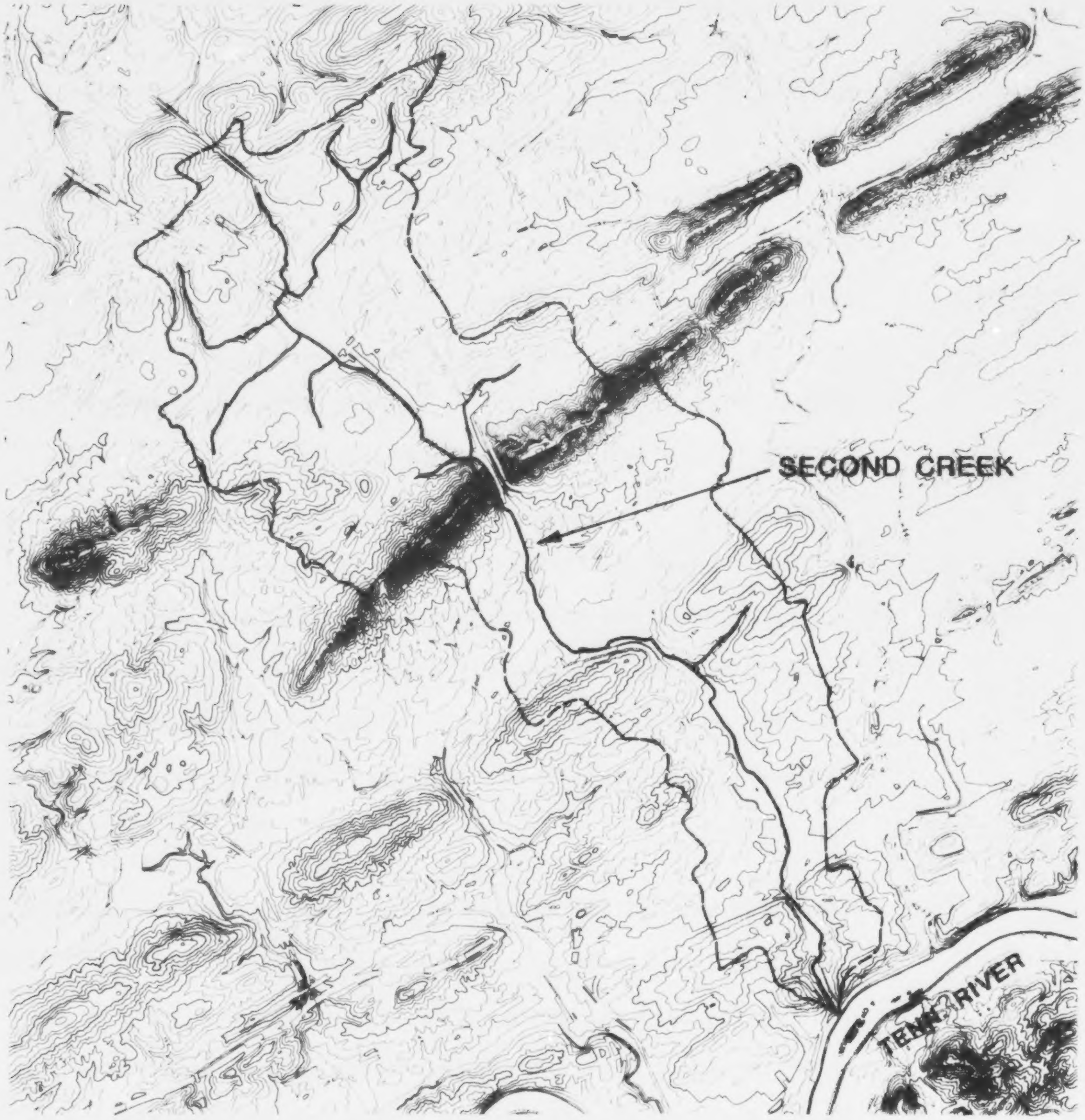

SECOND CREEK
TENN. RIVER

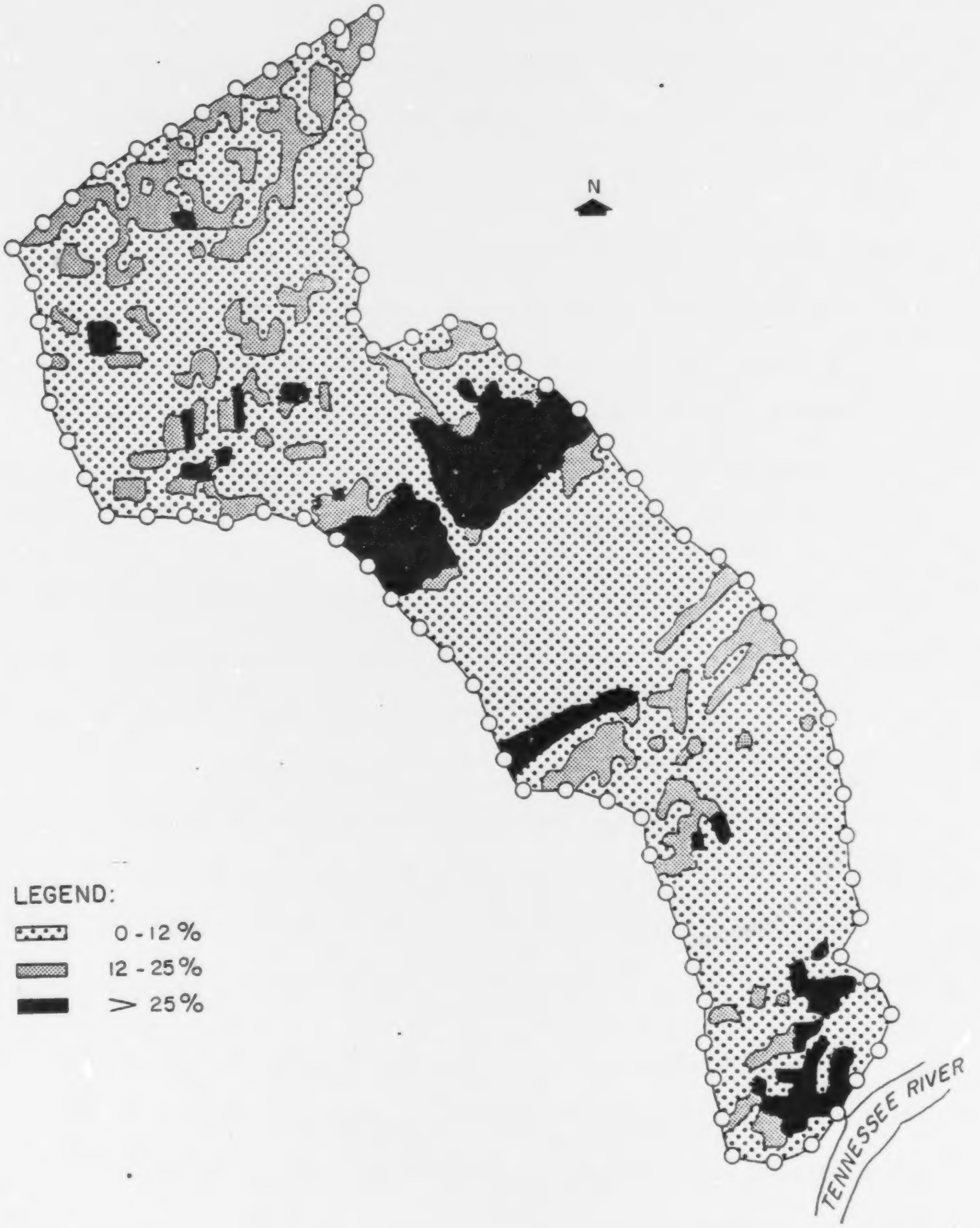
FIGURE II -4. SECOND CREEK DRAINAGE BASIN

on Sharp Ridge, where the geologic structure is complex, rocks are relatively insoluble (e.g., the Rome Formation), elevation is high, and slopes are steep.

Figure II-5 shows the slope distribution in the basin. Most slopes are less than 12 percent, but slopes steeper than 25 percent predominate on Sharp Ridge and in valley banks near the mouth of Second Creek. The gentler slopes at lower elevations generate relatively less runoff, but receive much from the steeper slopes above.

Elevations in Second Creek basin, shown in figure II-6, range mostly between 900 and 1100 feet. The maximum elevations are 1360 feet on Blackoak Ridge and 1400 feet on Sharp Ridge, both on the divide between First and Second Creeks. Along the divide between Second and Third Creeks, the maximum elevations are 1180 feet on Blackoak Ridge and 1340 feet on Sharp Ridge. The lowest elevation in the basin, at the mouth of Second Creek, is 810 feet. The local relief is 590 feet.

The geologic formations in the Second Creek watershed consist of the Ottosee Shale, Holston Formation, Lenoir Limestone, Knox Group (Mascot Dolomite, Kingsport Dolomite, Longview Dolomite, Chepultepec Dolomite, and Copper Ridge Dolomite), Conasauga Group (Maynardville Limestone, Nolichucky Shale, Maryville Limestone, Rogersville Shale, Rutledge Limestone, and the Pumpkin Valley Shale) and the Rome Formation (Cattermole, 1958 and 1966).


N
LEGEND:
0 - 12 %
12 - 25%
> 25%
TENNESSEE RIVER
0 FEET 4000

SECOND CREEK

FIGURE II - 5. SLOPE

(After Kung, 1980)

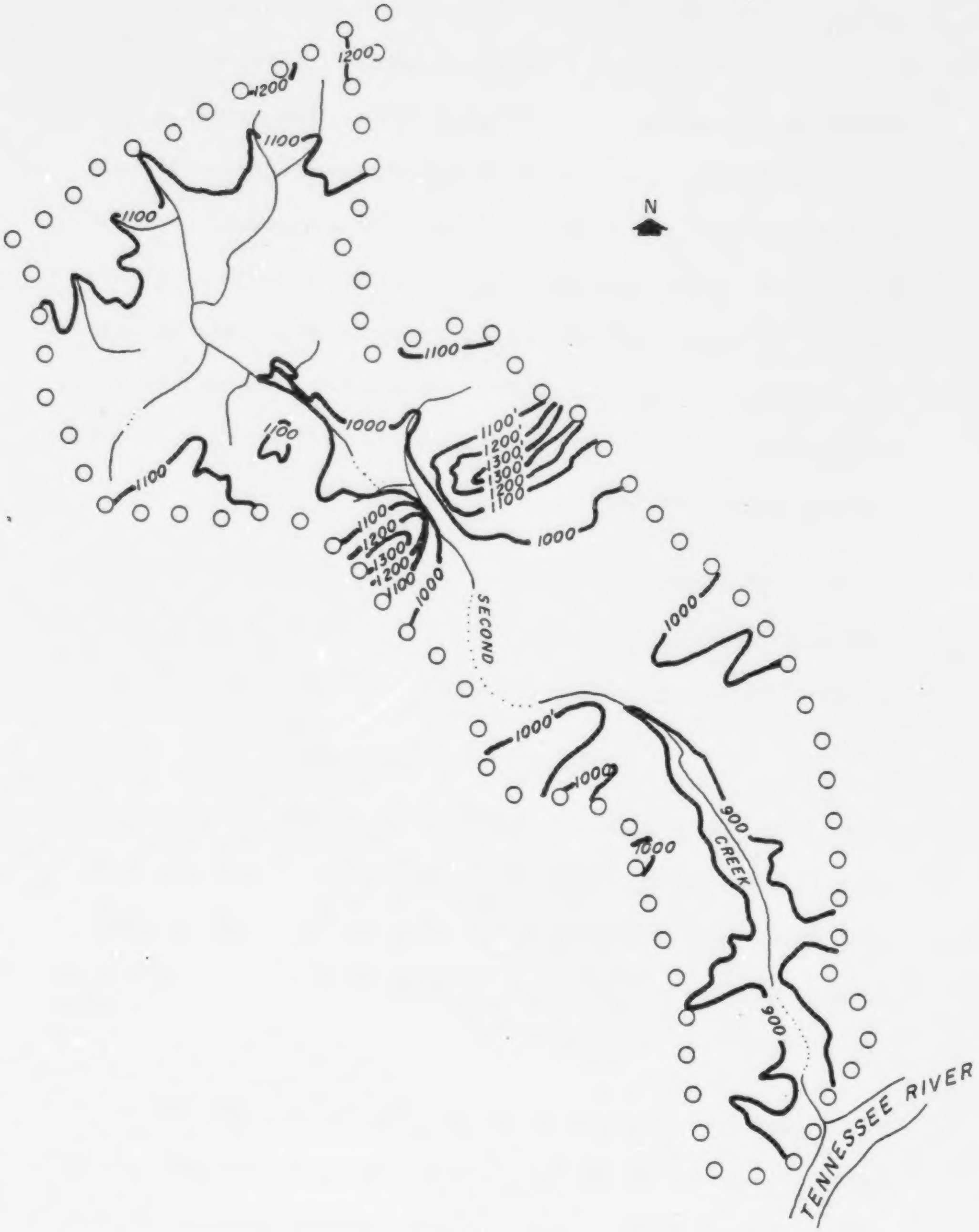

1200
1200
1100
1100
N
1100
1000
1100
1100'
1200'
1300'
1300
1200
1100
1100
1000
1100
1200
1300
1200
1100
1000
SECOND
1000
1000'
1000
1000
900
CREEK
900
TENNESSEE RIVER

FIGURE II - 6. SECOND CREEK ELEVATION DISTRIBUTION

(After Kung, 1980)

0
FEET
4000

The Ottosee Shale consists primarily of a brownish-gray, calcareous shale and siltstone. Limestone lenses occur in the formation in local areas. In the Second Creek watershed, sinkholes are common in the Ottosee Shale. The collapse features are caused by one of two processes as follows: (1) the limestone lenses are dissolved within the Ottosee by circulating groundwater, creating a void and ultimately a collapse in the roof of the cavity system; or (2) there is no structural support for the Ottosee when circulating groundwater creates a void and ultimately a collapse in the roof of the cavity system in the underlying Holston Formation.

The Holston Formation is a massively bedded, medium to coarsely crystalline, gray to brownish-red limestone. The Holston is one of the predominant cave-forming units in Knox County (Moore, 1973).

Underlying the Holston Formation is the Lenoir Limestone. This unit is composed of a nodular, argillaceous, light to medium gray limestone. Numerous sinkholes occur along the stratigraphic contact of the Lenoir and the Holston, particularly in the Second Creek watershed.

The sequence of rocks which stratigraphically underlies the Lenoir Limestone is the Knox Group. The Knox consists of light gray, gray, or blue, fine- to coarse-grained dolomite and some limestone. Nodules of chert are common throughout this sequence of rocks. The formations which make up the Knox Group of rocks in the Second Creek area (listed previously) have varying degrees of permeability and cavity development. For example, the Mascot Dolomite generally tends to be more soluble than the Copper Ridge dolomite. The Copper Ridge typically underlies some of the ridges in the study area.

Underlying the Knox Group of rocks is the Conasauga Group. The Conasauga Group consists of alternating sequences of limestone and shale units (listed previously). The limestone units are blue or gray, fine-textured, and ribboned, and usually do not contain chert. The shale units are many colors, such as green, brown, brownish-yellow, red, or gray, and may be silty, sandy, or calcareous.

The Rome Formation stratigraphically underlies the Conasauga Group. The Rome Formation is light-colored sandstone interbedded with drab red, purple, green, or brown siltstone and shale. In the Sharp Ridge area, the Rome has been superimposed over geologic units younger in age (i.e., the Rutledge Limestone and the Holston Formation).

Structurally, the Second Creek area is a series of folded and faulted rocks that resulted from compressive stresses of the Appalachian Mountain uplift. The linear pattern of geologic structure that resulted is oriented northeast-southwest, the direction of strike. The rocks dip at varying angles, generally to the southeast. Along Sharp Ridge the strata are nearly vertical. About a mile north of Sharp Ridge, a sequence of rocks has been structurally folded and faulted, forming a synclinal feature. That is, the rocks dip toward the middle of the feature or the longitudinal axis. The longitudinal axis of the syncline follows an overall northeast-southwest trend, and plunges toward First Creek.

In the Second Creek area, groundwater occurs in the fractures, joints, and along the bedding planes of the bedrock. The fractures in the carbonate formations (i.e., limestone, dolomite, calcareous shale) tend to be enlarged by circulating groundwater, creating solution cavities. In some of the carbonate formations in the study area, there has been extensive development of solution cavities. Large quantities of groundwater may circulate through these openings. Much of the cavern development occurs in the Holston Formation, secondly in the soluble units of the Knox Group, and last in the Maryville Limestone (Moore 1973).

The fractures in the noncalcareous shale, siltstone, and sandstone units in the Second Creek area are generally not susceptible to enlargement from circulating groundwater. Usually smaller quantities of groundwater are found in these formations than in the carbonate formations.

Lithology and structure influence groundwater movement across the study area. In general, groundwater movement follows the direction of the strike (northeast-southwest). Faults in the study area are believed to retard groundwater movement between geologic formations.

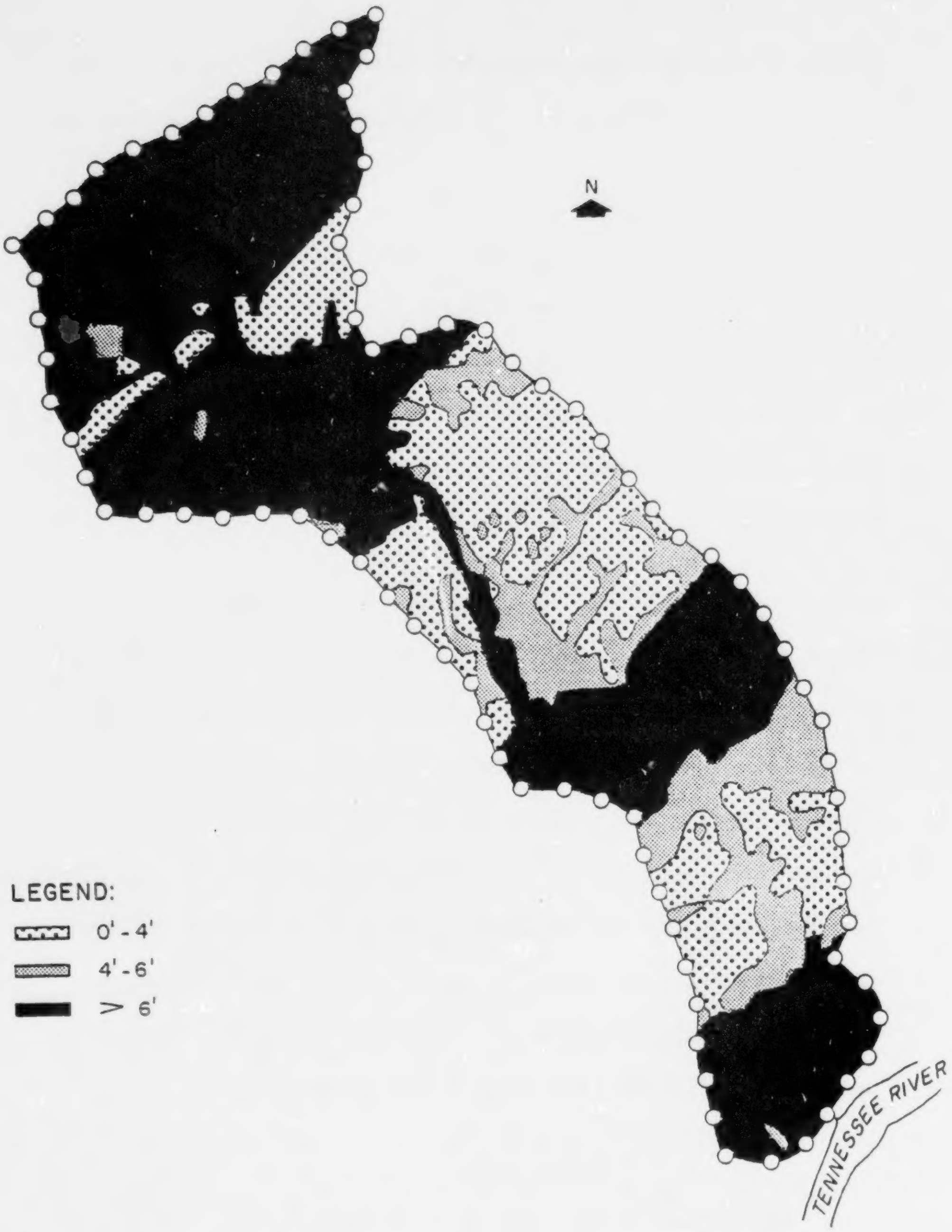
Soil depth and soil permeability, shown in figures II-7 and II-8, are similar to those of the First Creek basin. Deep soils and highly permeable soils are significantly related to one another and to the occurrence of carbonate rock. Shallow soils and less permeable soils predominate over the Nolichucky and Ottosee Shales.

Land use in the Second Creek drainage basin is shown in figure II-9. This basin is more urbanized than that of First Creek. Commercial developments are located downtown, along Central Avenue, and along Clinton Highway. Industrial use is extensive from Western Avenue to the Coster Yards of the Southern Railway. Because of this greater extent of industrial land and less open and forested lands than in the First Creek basin, a higher percentage of impervious surfaces and higher water yield would be expected. Table II-3 indicates the percentage of different land uses in the basin.

Table II-3

Percentage of Land Use in Second Creek Drainage Basin

	Single family	Multi-family	Commercial	Industrial	Open	Forest	Total	Total impervious
Percent (%)	54	8	12	8	11	7	100	26
Size (acres)	2454	364	545	364	499	318	4544	1181


N
LEGEND:
0'-4'
4'-6'
> 6'
TENNESSEE RIVER
0
FEET
4000

SECOND CREEK

FIGURE II-7. SOIL DEPTH

(After Kung, 1980)

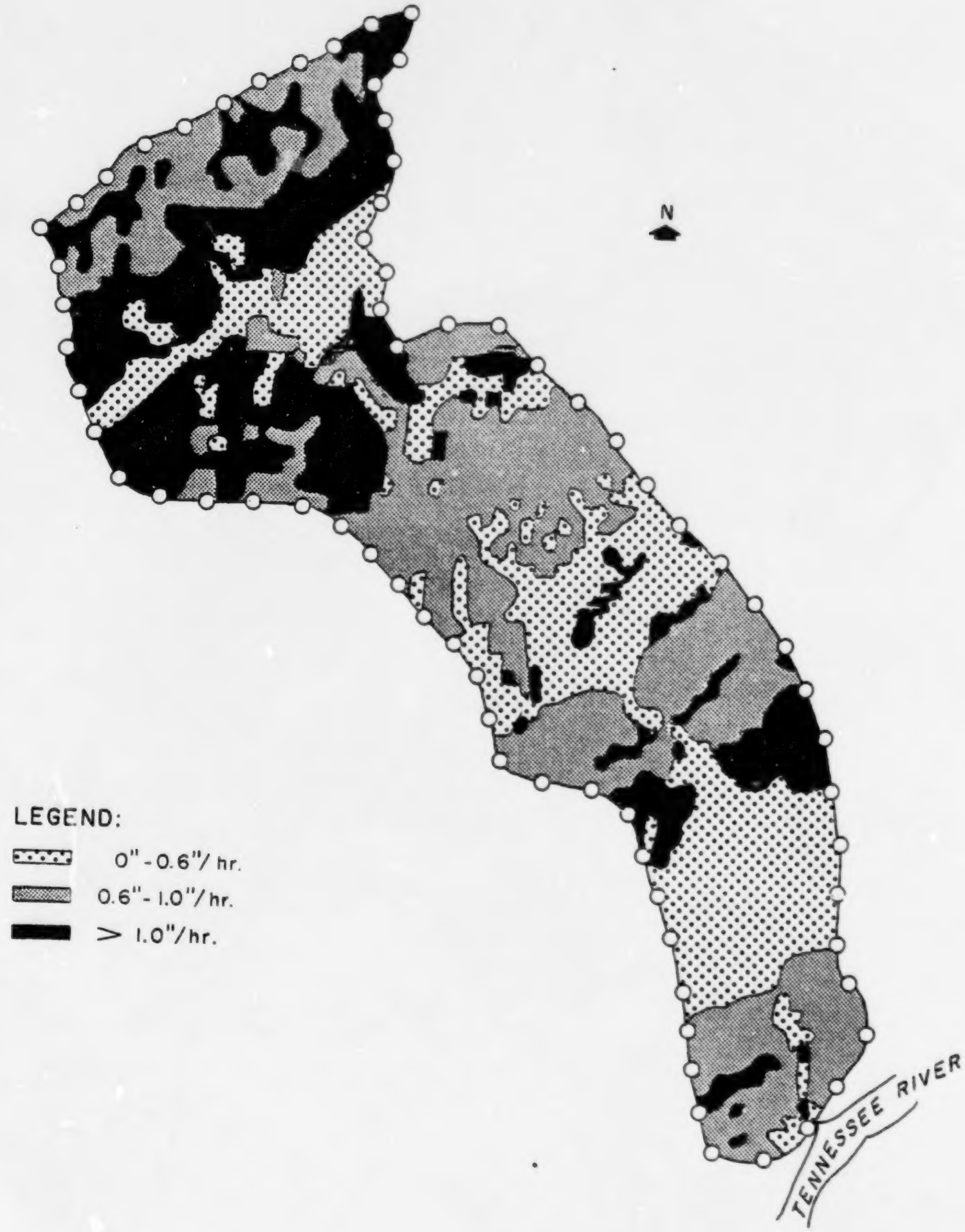
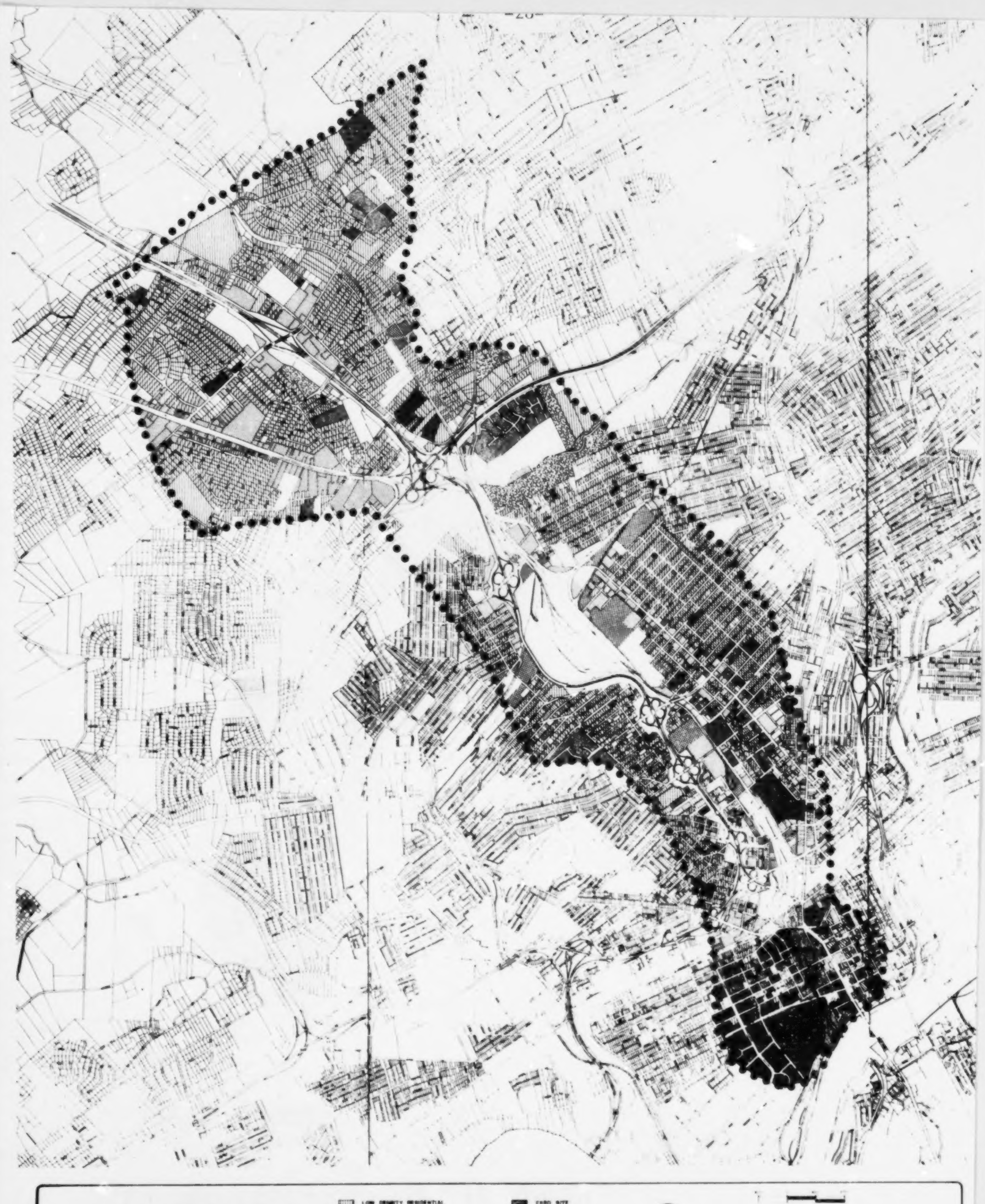

N
LEGEND:
0"-0.6"/hr.
0.6"-1.0"/hr.
> 1.0"/hr.
TENNESSEE RIVER
0
FEET
4000

FIGURE II - 8. SECOND CREEK SOIL PERMEABILITY

(After Kung, 1980)


LOW DENSITY RESIDENTIAL
COMMERCIAL
INSTITUTIONAL
OPEN SPACE
INDUSTRIAL
HIGH DENSITY RESIDENTIAL
UTILITIES / TRANSPORTATION
MEDIUM DENSITY RESIDENTIAL
EXPO SITE
VACANT
CBD PARKING

SECOND CREEK BASIN

FIGURE II -9. LAND USE

The areas of high potential water yields are concentrated on steep slopes, less permeable soils, and shale bedrock (fewer sinkholes), together with the more continuous and extensive impervious surfaces of commercial and industrial lands, which offer little chance for groundwater leakage. Conversely, the areas of potentially low yield in surface streams are predominantly in the upper parts of the basin and on the west side of the creek, where sinkholes and more soluble carbonate rocks, as well as more open land uses, occur. North of Sharp Ridge, where a complicated geologic structure of overthrust faults forms groundwater barriers, there is a high potential for water yield. The area along Merchants Drive is geologically impermeable because it is underlain by Ottosee Shale in a synclined structure. This combination produces small water losses and high water yield.

Water Quality Sampling Subbasins

Four subbasins within the First and Second Creek watersheds, representing three types of urban land use, were selected for detailed study. Two residential areas, designated R1 and R2, and a strip commercial area (designated SC) were selected in the Second Creek watershed. In the First Creek watershed, a subbasin within Knoxville's central business district (designated CBD) was selected for study. Additionally, two subbasins were selected in the Second Creek watershed for a study of the effect of carbonate geology on hydrologic transport of stormwater runoff. These two subbasins were designated upper sink

(US), and lower sink (LS). The location of each of the subbasins is shown in figure II-10.

The Residential 1 (R1) subbasin encompasses 69.0 acres of which 91 percent is typical medium density (three to eight dwellings per acre) single family dwellings which house a total population of approximately 750 persons. Ninety-two percent of the catchment is drained by separate storm sewers and the remainder by surface runoff. The representative slope of the catchment area is 179.5 ft/mile. The length of the main conveyance channel and its slope are respectively 160 ft and 263.9 ft/mile.

The Residential 2 (R2) subbasin encompasses 89.3 acres of which 74 percent is typical low density (one-half to two dwellings per acre) single family dwellings, which house a total population of 333 persons. Twenty-one percent of the catchment is rural, with less than one-half dwelling per acre. The catchment does not have storm sewers, drainage occurs through roadside ditches. The representative slope of the catchment area is 202.7 ft/mile. The length of the main conveyance channel and its slope are respectively 1600 ft and 281.5 ft/mile.

The strip commercial (SC) subbasin is a long and narrow catchment which encompasses 97.7 acres of which 63 percent is strip commercial development, and 35 percent is low density residential. The catchment has a population of 131 persons. Drainage is generally from businesses bordering the main

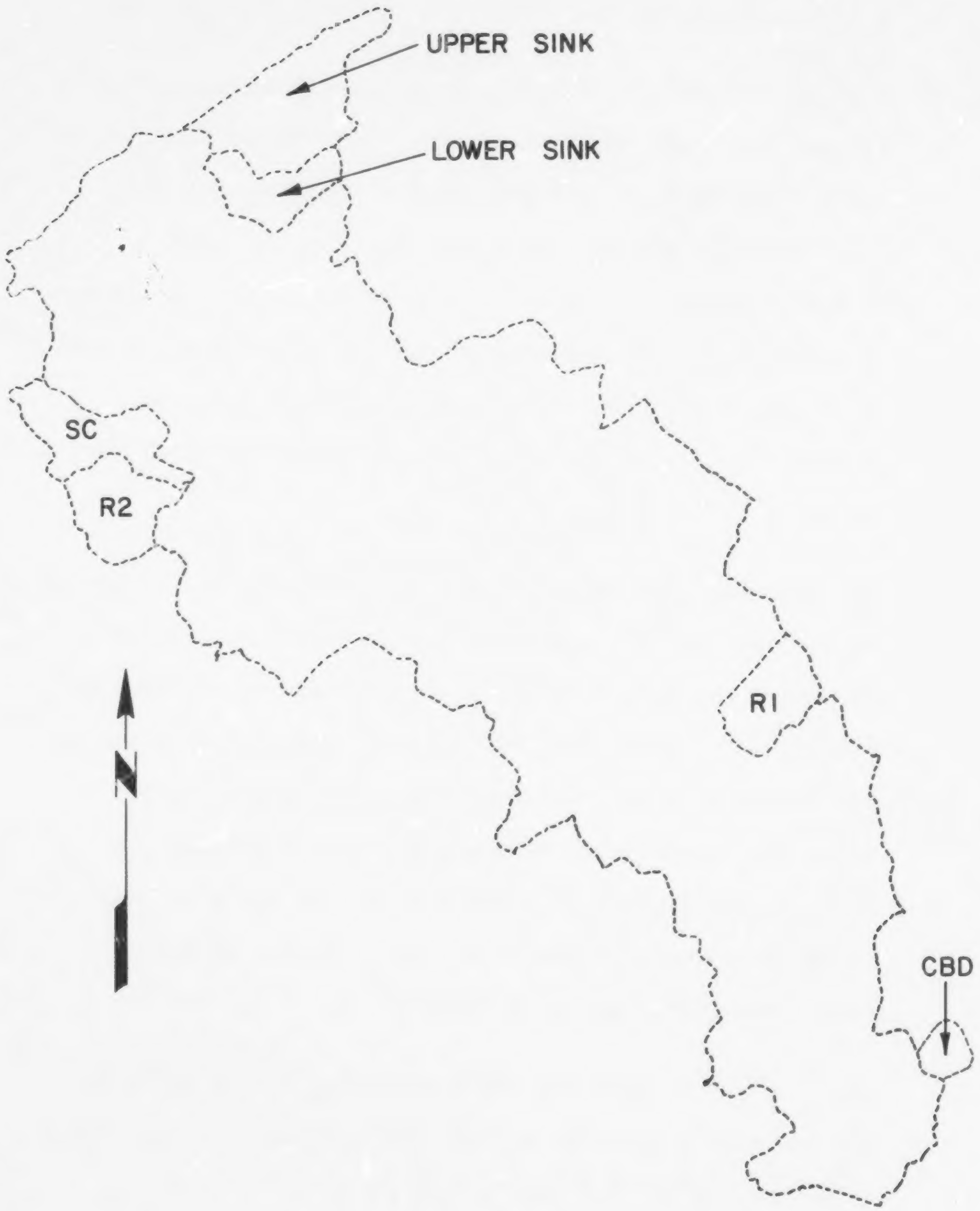

UPPER SINK
LOWER SINK
SC
R2
R1
N
CBD

FIGURE II-10. HYDROLOGICAL AND WATER QUALITY STUDY AREAS IN THE SECOND CREEK WATERSHED - KNOXVILLE, TENNESSEE.

thoroughfare in the catchment through a separate storm sewer system. The representative slope of the SC catchment is 190 feet per mile. The length of its main conveyance channel and its slope are respectively 2930 feet and 167.7 feet per mile.

The Central business district (CBD) subbasin encompasses 25.8 acres which can be classified as high density commercial. It is typical of a downtown metropolitan area, with numerous multi-story buildings and vast impervious areas (>99 percent). Drainage from the area is by separate storm sewers to the First Creek watershed. The representative slope of the catchment area is 322.6 feet per mile. The length of the main conveyance channel and its slope are respectively 693 feet and 437.5 feet per mile.

The upper sink (US) and lower sink (LS) subbasins contain respectively 178.7 and 255.8 acres. These catchments are adjacent to each other and their land use is typical suburban, low density, single family residential. The representative slopes of the US and LS catchments are respectively 529.5 and 494.4 feet per mile. The length of the US main conveyance channel and its slope are respectively 2400 feet and 299 feet per mile. The length of the LS main conveyance channel and its slope are respectively 4600 feet and 113 feet per mile.

Additional characteristics (fixed site data) of the four water quality study basins (R1, R2, SC, CBD) are given in table II-4. It should also be noted that all six of the study basins are served by separate sanitary sewer systems.

Table II-4

Fixed Site Data - Knoxville, Tennessee
Urban Runoff Study

Catchment	Area (acres)	Population	Catchment slope (ft/mi)	Channel slope (ft/mi)	Channel length (ft)	Impervious area (percent)	Road type	Land Use Percent			
								Residential	Strip Commercial	Business	Other
R1	69.0	748	179	263	1600	32	Asphalt	91	0	0	9
R2	89.3	333	202	281	1600	13	Asphalt	94	4	0	2
SC	97.7	131	190	167	1330	68	Asphalt	36	63	0	1
CBD	25.8	0	322	437	693	99	-	0	0	100	0

III. Data Collection

A. Instrumentation

In order to effectively characterize urban runoff, rainfall and atmospheric deposition data as well as runoff water quality data were collected. Rainfall records for the study period were compared with historical records to evaluate the study period's representativeness (with respect to total rainfall) of previous years. The water quality data, along with total flow records, allowed the calculation of average pollutant storm loadings introduced into the receiving water body (initially Second Creek and ultimately the Tennessee River) through urban runoff. And finally, the wetfall and dryfall atmospheric deposition data provided a means of determining atmospheric deposition's contribution to the urban runoff pollutant loads.

Each of the four water quality sampling sites (CBD, R1, R2, and SC) were instrumented with basically the same equipment. All water (runoff and base flow) flowed through a Palmer-Bowlus flume and its level was monitored by a continuous recording stage recorder and an ISCO flow meter. The ISCO flow meter was connected to two automatic water samplers (one for discrete sample collection and the other for composite collection) to allow flow proportional sample collection. Rainfall was continually monitored by a recording rain gage. And lastly, wetfall and dryfall samples were collected by an AEC type atmospheric deposition collector.

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Flow Recording Equipment

1. Friez (FW-2) Water Level Recorders

   Friez (FW-2) water level recorders, modified to accommodate a strip chart, were used to obtain continuous records of the flow at each of the four water quality sites and at the upper and lower sink sites. The FW-2 is a float-type recorder powered by a spring-operated clock mechanism. A cable connects the float to a pen which records the water level on a strip chart. At each site the float was housed in a stilling well to protect it from floating debris and also to reduce water level fluctuations due to turbulence.

   Once reduced and computerized, the strip charts provided the following data: instantaneous flow rate (ft^3/sec), total flow (gallons) per storm event, total flow during the "sampling period"* (gallons), and the duration of the storm related runoff (hours).

2. ISCO Model 1700 Flow Meter and Model 1710 Printer

   The flow through the flume was monitored by an ISCO Model 1700 flow meter, in conjunction with the ISCO Model 1710 digital printer, to provide a backup (to the FW-2) record of the total flow. The ISCO flow meters main function was to drive the ISCO automatic water samplers.

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*"Sampling period" refers to the period of time that the runoff stage was greater than, or equal to 0.3 ft.

The Model 1700 flow meter operates on a "bubble principle." The end of a small plastic tube is anchored at a fixed depth in the flume. Air, furnished by a small internal compressor, is expelled through the tube at a constant rate. The back pressure in the tube corresponds to the hydraulic head of the water level in the flume. An electronic pressure transducer measures and converts to an electronic signal the pressure in the tube. This signal is converted to a flow rate by a function generator disk internal to the flow meter. The ISCO Model 1710 digital printer, operating in conjunction with the 1700 flow meter, prints the totalized flow on a paper tape.

The ISCO Model 1710 digital printer records both incremental and total flow information. The time of day, day of the month, and month of the year are also recorded. The total flow data is printed, in digital form, in the same units as were programmed into the ISCO flow meter. It is important to note that a time integrated flow rate is recorded (i.e., gallons, cubic feet, etc.) and not an instantaneous flow rate (i.e., gallons per second, cubic feet per second, etc.). The Model 1710 can be set to print at 5, 10, 15, 20, 30, or 60 minute intervals and when the printer is working in conjunction with an automatic water sampler the 1710 prints the total flow each time the sampler initiates a sampling cycle. In order to distinguish between the routine printing and the sampling cycle initiated printing, the recorder prints the letter "T" on the right edge of the paper tape to indicate the time-initiated print and the letter "S" to indicate sampler-initiated print.

The flow meter also initiates the flow proportional sample collection. The Model 1700 flow meter transmits an electronic signal (or flow pulse) to the automatic water sampler each time a preprogrammed volume of water passes through the flume. The automatic samplers, in turn, are programmed to collect a water sample after receiving a certain number of flow pulses.

3. ISCO Model 1870 Flow Meter

The ISCO Model 1870 flow meter, which was used only at the SC site, is similar to the Model 1700 with the main difference that the Model 1870 includes a built-in strip chart recorder to record flow rate which precluded the need for the Model 1710 printer at this site.

The Model 1870 operates on the same bubble principle as the Model 1700. The Model 1870 also transmits flow proportionate electronic signals to the automatic water sampler for flow proportional sample collection. The pen places an event mark at the bottom of the chart each time a sample is collected.

The flow records from the Model 1710 printer and the Model 1870 strip chart provided backup flow data in case the FW-2 stage recorder ever malfunctioned.

4. Automatic Water Samplers

The runoff samples were collected by ISCO Model 2100 automatic water samplers. Two samplers were housed at each site, one for composite sample collection and the other for the collection of discrete samples.

These samplers are capable of collecting water samples flow proportionally or on a time sequence. However, during this study only flow proportional sampling was done.

For standard water quality constituents and metals, composite samples were collected in a 5-gallon polyethylene container and discrete samples in 1000-ml polypropylene bottles. A 2.5-gallon glass bottle (for composite samples) and 350-ml glass bottles (for discrete samples) were used when collecting samples to be analyzed for priority pollutants.

Water samples were collected when the stage was greater than or equal to 0.3 foot. This was necessary to avoid repeated clogging of the sample intake line which occurred at lower stages. The samplers were connected to a float switch, installed just upstream from the flume, which prevented them from receiving flow pulses from the flow meter when the stage was below 0.3 foot. When the water level (and float) rose, the float completed the circuit with the switch and allowed the sampler to receive pulses from the flow meter.

5. Rain Gages

Five weighing-type precipitation gages were used during this study to measure the amount and intensity of precipitation during each storm. One gage was located in each of the four water quality study subbasins and one in the subsurface drainage study area that included the upper and lower sink sites.

These gages provide a continuous record of rainfall. The precipitation is collected in a bucket sitting on the platform of a spring balance. A pen linked to the balance records the weight of the bucket, plus any precipitation, on a strip chart. The gages are mechanically powered by a clock mechanism.

All gages were placed so that neither trees nor obstacles subtended the gages at angles greater than 45 degrees from the top of the gage.

The strip charts were collected and buckets emptied on a weekly basis. Once reduced and computerized, these records provided hourly, daily, and monthly rainfall totals (inches); total rainfall per storm event (inches);

storm duration (hours), intensities (inches per hour), and antecedent dry period (days).

6. Atmospheric Deposition Collectors

Wetfall/dryfall atmospheric deposition collectors were installed near the rain gages in each of the study subbasins (CBD, R1, R2, and SC).

The collectors used were designed by TVA. Their design and operation is very similar to the Aerochem Metric's collectors except that TVA's bucket diameter is 7.5 inches while the diameter of the Aerochem Metric's bucket is 11 inches. A statistical comparison of sample data from these two types of collectors indicated no significant difference between these sampling devices (see Appendix A for details).

The wetfall/dryfall collectors are equipped with two buckets, one for wet deposition and the other for dry deposition. When precipitation begins, the dryfall bucket is covered by a stainless steel hood. As soon as the precipitation ends, the hood automatically moves to cover the wetfall bucket.

7. Power Supply

All water samplers, ISCO flow meters, and ISCO printers were powered by automotive batteries that were trickle-charged with ac voltage. The batteries and trickle-chargers were used rather than direct connection to

The ac line so that storm-related power outages would never affect sample collection.

The atmospheric deposition collectors were connected directly to the ac line power. (Short power outages would not affect their sample collection.)

B. Sample Collection and Laboratory Analyses

The following is a discussion of the sample collection schedules, the preservation techniques used, and the analyses performed on all samples. The laboratory employed was TVA's Laboratory Branch in Chattanooga, Tennessee. All samples were shipped to the laboratory by a special intercity shuttlebus. Because of the proximity of the laboratory (two hours from the study area), holding times greater than 24 hours were never experienced.

All samples with the exception of the base flow samples and a percentage of the dryfall samples, were collected on a storm event basis. A "storm event" was defined as beginning at the start of precipitation and ending when the last rainfall was followed by six consecutive hours without rain.

1. Base Flow Samples

Base flow samples were collected at the CBD and SC sites (the only sites with a base flow) for the purpose of calculating average constituent loading rates not resultant of surface runoff.

The CBD site was sampled twice, once on June 14, 1981, and again on June 15, 1981. The first sample was representative of night-time flow. It was collected flow proportionally, one sample per 300 cubic feet, between 4:45 p.m. and 6:35 a.m. The second composite sample, also collected flow proportionally, was representative of day-time flow. It was collected between 7:20 a.m. and 6:40 p.m.

Three baseline composite samples were collected at the SC site, one on June 11, 1981, and the other two (field duplicates) on June 17, 1981.

The samples were cooled to 4°C in ice-filled coolers and shipped to the laboratory for the analysis of the constituents listed in table III-1.

2. Runoff Samples

Runoff samples were collected during all storm events that produced sufficient runoff to activate the samplers (stage $\geq$0.3 foot). The samples were always collected flow proportionally over the hydrograph and were either a composite or several discrete samples. Table III-2 shows the schedule of composite and discrete sample collections at each of the four sites.

A "storm number" was assigned to each event sampled. This number was coincident at all stations. For example, when samples were collected at one site, a "storm number" was

Table III-1

Constituents Analyzed in Baseline Samples

pH
Total dissolved solids
Total suspended solids
Nitrate nitrite
Ammonia ammonium
Total kjeldahl nitrogen
Dissolved kjeldahl nitrogen
Total phosphorus
Dissolved phosphorus
Soluble organic carbon
Total organic carbon
Chemical oxygen demand
Fecal coliform
Fecal streptococcus
Biochemical oxygen demand (5-day)
Alkalinity

Total sulfate
Total chloride
Total calcium
Total magnesium
Total sodium
Total potassium
Total copper
Total zinc
Total chromium
Total selenium
Total mercury
Total nickel
Total cadmium
Total lead
Total iron
Total manganese

Table III-2

Runoff Sample Collection Schedule

Site: Central Business District (CBD)

Storm identification number	Storm beginning		Storm ending		Sample collection method
	Date	Time	Date	Time	
1	07-01-81	20:50	07-02-81	07:30	Composite
2	08-06-81	09:40	08-06-81	19:39	Composite
3	08-08-81	00:47	08-08-81	03:50	Composite
4	-	-	-	-	Sample not taken
5	08-16-81	10:07	08-16-81	12:25	Composite
6	08-18-81	14:24	08-18-81	20:16	Composite
7	08-20-81	21:51	08-21-81	08:17	Composite
8	09-14-81	22:38	09-15-81	13:27	Composite
9	-	-	-	-	Sample not taken
10	10-01-81	20:07	10-02-82	03:50	Composite priority pollutants
11	10-23-81	02:35	10-23-81	15:54	Discrete
12	10-26-81	19:00	10-27-81	08:00	Composite
13	11-19-81	21:33	11-20-81	04:06	Composite
14	11-23-81	20:22	11-24-81	05:48	Composite
15	11-30-81	11:10	12-01-81	15:40	Composite
16	-	-	-	-	Sample not taken
17	01-22-82	05:35	01-23-82	12:26	Composite
18	02-02-82	10:30	02-03-82	05:45	Composite priority pollutants
19	02-09-82	03:44	02-09-82	19:39	Composite
20	03-04-82	20:10	03-05-82	06:28	Composite
21	03-21-82	04:49	03-21-82	14:01	Discrete
23	03-25-82	17:38	03-25-82	21:43	Composite
24	03-31-82	16:05	03-31-82	18:00	Discrete
25	04-08-82	07:10	04-08-82	16:53	Discrete
26	-	-	-	-	Sample not taken
27	04-17-82	08:27	04-17-82	20:10	Discrete

Table III-2

(Continued)

Runoff Sample Collection Schedule

Site: Residential 1 (R1)

Storm identification number	Storm beginning Date	Time	Storm ending Date	Time	Sample collection method
1	07-01-81	20:53	07-01-81	22:02	Composite
2	08-06-81	10:11	08-06-81	11:47	Composite
3	-	-	-	-	Sample not taken
4	-	-	-	-	Sample not taken
5	-	-	-	-	Sample not taken
6	-	-	-	-	Sample not taken
7	08-20-81	22:47	08-21-81	06:40	Composite
8	09-15-81	02:02	09-15-81	10:36	Composite
9	09-15-81	17:46	09-15-81	23:45	Composite
10	10-01-81	22:16	10-02-81	00:44	Composite priority pollutants
11	10-23-81	04:12	10-23-81	14:39	Composite
12	10-26-81	19:31	10-27-81	01:40	Composite
13	11-19-81	22:59	11-20-81	00:33	Discrete
14	11-23-81	23:14	11-24-81	02:27	Composite
15	11-30-81	13:05	12-01-81	10:57	Discrete
16	01-20-82	22:34	01-21-82	07:25	Composite
17	01-22-82	07:08	01-23-82	10:55	Composite
18	02-02-82	11:12	02-03-82	03:59	Composite
19	02-09-82	04:08	02-09-82	18:27	Composite priority pollutants
20	-	-	-	-	Sample not taken
21	03-21-82	05:28	03-21-82	12:20	Discrete
22	03-25-82	17:43	03-25-82	18:45	Composite samples not analyzed
23	03-31-82	06:23	03-31-82	09:47	Composite samples not analyzed
24	-	-	-	-	Sample not taken
25	-	-	-	-	Sample not taken
26	-	-	-	-	Sample not taken
27	04-17-82	08:35	04-17-82	14:30	Discrete

Table III-2

(Continued)

Runoff Sample Collection Schedule

Site: Residential 2 (R2)

Storm identification number	Storm beginning		Storm ending		Sample collection method
	Date	Time	Date	Time	
1	07-01-81	20:49	07-02-81	00:56	Composite
2	08-06-81	09:50	08-06-81	11:33	Composite
3	-	-	-	-	Sample not taken
4	08-11-81	21:37	08-12-81	01:12	Composite
5	-	-	-	-	Sample not taken
6	-	-	-	-	Sample not taken
7	08-20-81	22:20	08-21-81	06:16	Composite
8	09-15-81	01:45	09-15-81	11:09	Composite
9	09-15-81	17:26	09-15-81	23:27	Composite
10	10-01-81	21:25	10-02-81	00:21	Composite priority pollutants
11	10-23-81	03:03	10-23-81	13:44	Discrete
12	10-26-81	19:10	10-27-81	04:43	Composite
13	-	-	-	-	Sample not taken
14	11-23-81	22:23	11-24-81	02:21	Composite (no samples)
15	-	-	-	-	Sample not taken
16	-	-	-	-	Sample not taken
17	01-22-82	06:35	01-24-82	01:25	Composite
18	02-02-82	10:37	02-04-82	00:26	Composite priority pollutants
19	02-09-82	03:48	02-10-82	08:03	Composite
20	-	-	-	-	Sample not taken
21	03-21-82	04:57	03-21-82	18:07	Composite
22	03-25-82	17:30	03-25-82	23:00	Discrete
23	03-31-82	05:42	03-31-82	13:00	Composite
24	-	-	-	-	Sample not taken
25	-	-	-	-	Sample not taken
26	04-15-82	20:12	04-16-82	01:37	Discrete
27	04-17-82	08:29	04-17-82	22:22	Discrete

Table III-2

(Continued)

Runoff Sample Collection Schedule

Site: Strip Commercial (SC)

Storm identification number	Storm beginning		Storm ending		Sample collection method
	Date	Time	Date	Time	
1	07-01-81	20:44	07-02-81	08:19	Composite (not analyzed)
2	08-06-81	09:32	08-06-81	14:34	Composite
3	08-07-81	21:00	08-08-81	06:53	Composite
4	08-11-81	21:37	08-12-81	11:17	Composite
5	-	-	-	-	Sample not taken
6	08-18-81	15:18	08-18-81	18:44	Composite
7	08-20-81	21:58	08-21-81	11:10	Composite
8	09-14-81	21:58	09-15-81	16:12	No samples analyzed
9	09-15-81	17:14	09-16-81	01:42	Composite
10	10-01-81	20:00	10-02-81	03:12	Composite priority pollutants
11	10-23-81	02:41	10-24-81	03:50	Discrete
12	10-26-81	18:53	10-27-81	18:32	Composite
13	-	-	-	-	Sample not taken
14	11-23-81	20:21	11-24-81	07:23	Composite
15	11-30-81	11:28	12-01-81	20:59	Composite
16	-	-	-	-	Sample not taken
17	01-22-82	06:35	01-24-82	00:29	Composite
18	02-02-82	10:32	02-03-82	23:16	Composite priority pollutants
19	02-09-82	03:54	02-10-82	07:25	Composite
20	-	-	-	-	Sample not taken
21	03-21-82	04:47	03-21-82	15:13	Composite
22	03-25-82	17:30	03-26-82	06:48	Discrete
23	03-31-82	05:29	03-31-82	15:39	Composite
24	-	-	-	-	Sample not taken
25	04-08-82	06:59	04-08-82	19:00	Discrete
26	04-15-82	20:18	04-16-82	06:00	Discrete
27	04-17-82	08:28	04-18-82	03:30	Discrete

given to that event regardless of whether or not samples were collected at other sites. When samples were not collected it was usually due to insufficient runoff to activate the sampler or equipment malfunctions.

Following the end of each storm event (i.e., six consecutive hours without rain following the last precipitation), the fieldcrew examined the samples and if satisfactory prepared them for shipment to the laboratory. If the samples were of insufficient volume for analysis, were found to be contaminated, or for some reason were not representative of the storm, they were discarded.

If the storm duration was anticipated to be greater than 24 hours, fieldcrews packed ice around the sample container to aid in preservation of the sample while the collection was ongoing; otherwise, after collection the samples were packed in ice-filled coolers for transport to the laboratory. The composite and discrete samples were analyzed for the constituents listed in table III-3. The analytical procedures for these analyses are listed in the quality assurance program description in Appendix B.

Midway through the sample collection phase of the study, the data was reviewed and certain constituents dropped from analysis. The constituents deleted were chloride,

Table III-3

Constituents Analyzed in Composite and Discrete Runoff Samples[a]

pH
Conductivity
Total dissolved solids
Total suspended solids
Nitrate nitrite
Ammonia ammonium
Total kjeldahl nitrogen
Total phosphorus
Dissolved phosphorus
Soluble organic carbon
Total organic carbon
Chemical oxygen demand
Fecal coliform
Fecal streptococcus
Biochemical oxygen demand (5-day)
Biochemical oxygen demand (20-day)
Alkalinity
Total sulfate
Total chloride
Total calcium
Total magnesium
Total sodium
Total potassium
Total copper
Dissolved copper
Total zinc
Dissolved zinc
Total chromium
Dissolved chromium
Total selenium
Dissolved selenium
Total mercury
Dissolved mercury
Total nickel
Dissolved nickel
Total cadmium
Dissolved cadmium
Total iron
Dissolved iron
Total manganese
Dissolved manganese
Total aluminum
Dissolved aluminum

[a] The analysis of several constituents was discontinued because of sustained low levels in all samples. Those constituents dropped are indicated by the missing data in Appendix E.

sodium, potassium, sulfate, selenium (total and dissolved), mercury (dissolved), and nickel (total and dissolved). They were eliminated because their concentrations were nearly always found to be below the detection limit.

3. Atmospheric Deposition Samples

Atmospheric deposition samples were collected concurrent with each runoff sample.

The wetfall samples were collected on a storm event basis. Each sample was assigned the same "storm number" associated with the runoff samples.

The dryfall samples were collected over the interim between storm events during the period between July 1981 and October 1981, and on a monthly basis between November 1981 and the end of the study. The pre-October 1981 samples were also assigned a "storm number," linking them with the appropriate wetfall and runoff samples. Those samples collected on a monthly basis were referenced in accordance with the correct month. The change to monthly dryfall collection was made to provide a longer collection period which resulted in an increase in the mass of constituent accumulation. This provided data more amenable to loading calculations.

Additionally, it enabled data transfer to the National Atmospheric Deposition Program, which collects dryfall on a monthly basis.

Great care was taken by the fieldcrew to prevent contamination of the buckets by small, insignificant showers. During the storm associated dryfall collections, when showers produced runoff but not of sufficient volume to activate the water samplers, both the wetfall and dryfall buckets were changed. If the shower resulted in no runoff only the wetfall buckets were changed.

Wetfall and dryfall samples were sent to the laboratory immediately after collection and analyzed for the constituents listed in table III-4. The details of the collection procedures and analytical techniques are again given in Appendix B.

4. Priority Pollutants

Runoff samples were collected at each of the four water quality sites (CBD, SC, R1, R2) during two storm events and analyzed for 127 of the 129 priority pollutants (asbestos and dioxin were excluded). The dates of collection were October 1, 1981 and February 3, 1982.

During collection, two automatic water samplers were used at each site--one for discrete sample collection and the other for composite collection. All samples were collected flow proportionally, with the exception of grab samples for volatile organic acids (VOA) analysis.

The samplers were programmed in such a manner that each time the composite sampler took a sample, the discrete

Table III-4

Constituents Analyzed in Wetfall and Dryfall Samples

pH[a]
Conductivity[a]
Total dissolved solids[a]
Total suspended solids[a]
Total solids
Total Kjeldahl nitrogen
Total phosphorus
Total organic carbon
Chemical oxygen demand
Total calcium
Total magnesium
Total sodium
Total potassium
Total sulfate
Total chloride
Total iron
Total manganese
Total copper
Total zinc
Total chromium
Total selenium
Total mercury
Total nickel
Total cadmium
Total lead
Total aluminum
Nitrate nitrite

[a] Analyzed in wetfall only.

sampler filled four separate bottles consecutively (A, B, C, and D). At the end of the storm, the discrete bottles were manually composited into four separate samples (i.e., all "A" samples were composited, all "B" samples were composited, etc.). The samples were then poured into predosed preservative bottles, packed in ice and sent to the laboratory for analysis.

The composite samples were analyzed for base/neutral organics and acid extractable organics. The four discrete samples were analyzed for metals, phenols, cyanides, and oil and grease. In addition, one grab sample was collected at each site for the analysis of volatile organic acids. The analytical procedures used for the priority pollutant analysis are given in Appendix B.

C. Data Storage

All water quality, rainfall, atmospheric deposition, and flow data gathered during this study were stored on the Environmental Protection Agency's computerized data storage system (STORET). With the exception of the monthly dryfall data, all data related to the four water quality sampling stations (CBD, R1, R2, and SC) are stored on a storm event basis.

Each sampling station is assigned an agency and station code. The agency code, unique to TVA, is 131TVAC. The station codes associated with each sampling site are listed in table III-5.

Table III-5

Station Codes, Knoxville Urban
Runoff Study

Station Code	Station I.D.	Associated Data
N47001	CBD	Water quality, flow
N47002	CBD	Rainfall
N47003	CBD	Wetfall/dryfall
N47004	R1	Water quality, flow
N47005	R1	Rainfall
N47006	R1	Wetfall/dryfall
N47007	R2	Water quality, flow
N47008	R2	Rainfall
N47009	R2	Wetfall/dryfall
N47010	SC	Water quality, flow
N47011	SC	Rainfall
N47012	SC	Wetfall/dryfall

In addition to the agency and station codes, each parameter is assigned a unique STORET code. These parameter codes are listed in Appendix C.

Data from composite samples have been stored with their associated beginning and ending sampling dates and times. Discrete samples are stored with the instantaneous date and time of collection.

For each composite sample, three types of flow information are stored: total runoff flow in thousands of gallons, total flow greater than 0.3 feet stage in thousands of gallons, and instantaneous flow rates (ft^3/sec) at approximately 10-minute intervals over the hydrograph.

Parameter codes used for dryfall data are the same codes routinely used for sediment samples. Thus, prior to entry into STORET all dryfall data were converted from mg/L (the resulting unit after aqueous suspension of dryfall for analysis purposes) to mg of constituent/kg of total solids. The calculation is as follows:

$$A = B/TS$$

where: A = constituent accumulation (mg/kg)

B = constituent concentration (mg/L)

TS = total solids concentration (mg/L)

Also stored is the solids accumulation rate (SAR) associated with each dryfall sample, and is calculated as follows:

$$SAR = \text{grams/sq meter per day}$$

where: SAR = solids accumulation rate (gm/m^2 per day)

grams = total solids dry weight (gm)

sq meter = surface area of dryfall bucket (m^2)

day = duration of time the dryfall bucket is uncovered (days)

IV. Hydrologic Data

A. Rainfall-Runoff Data for Project Watersheds

Summaries of rainfall and runoff data are presented in tables IV-1 through IV-4 for the four watersheds sampled for storm runoff quality: Residential sites R-1 and R-2, Strip Commercial site (SC), and the Central Business District (CBD). These tables show the total precipitation for each storm sampled, the storm duration and intensity, and the associated storm runoff. Additional storm event data are also presented in Appendix D.

Tables IV-5 through IV-10 present the daily rainfall and runoff for water years 1981 and 1982 in two watersheds selected for a detailed study of the hydrologic effects of drainage into soluble carbonate rocks. The Upper Sink site (US) is located upstream from a reach of stream with coarse gravel in the channel and the Lower Sink site (LS) is located downstream. The rainfall units are inches of depth and the runoff units are in watershed-inches.

B. Analysis of Historic Rainfall Data

Long-term hourly precipitation data measured at the National Oceanographic and Atmospheric Administration (NOAA) weather station located at the Knoxville airport were analyzed in order to place the storm rainfall data collected at the project watersheds into perspective. These data were obtained

Table IV-1

Sampled Storms
Residential Site (R1)

Storm	Date	Rainfall (inches)	Duration (hours)	Intensity (in/hr)	Runoff (inches)
1	07-01-81	1.50	2.17	0.69	0.03
2	08-06-81	0.37	1.67	0.22	0.01
7	08-21-81	1.30	8.00	0.16	0.06
8	09-15-81	0.95	8.00	0.12	0.06
9	09-15-81	0.86	6.00	0.14	0.06
11	10-23-81	0.98	9.33	0.11	0.04
12	10-26-81	0.81	4.83	0.17	0.08
13	11-19-81	0.22	1.00	0.22	0.01
14	11-23-81	0.46	6.00	0.08	0.02
15	11-30-81	1.09	14.00	0.08	0.07
19	02-09-82	1.00	7.00	0.14	0.10
21	03-21-82	0.91	6.67	0.14	0.07
22	03-25-82	0.22	0.50	0.44	0.01
23	03-31-82	0.41	3.33	0.12	0.02
27	04-17-82	0.76	6.50	0.12	0.05
Average		0.79	5.67	0.20	0.05

Table IV-2

Sampled Storms
Residential Site (R2)

Storm	Date	Rainfall (inches)	Duration (hours)	Intensity (in/hr)	Runoff (inches)
1	07-01-81	0.89	2.17	0.41	0.05
2	08-06-81	0.38	1.83	0.21	0.01
4	08-11-81	0.47	1.17	0.40	0.02
7	08-21-81	1.40	7.67	0.18	0.06
8	09-15-81	1.20	8.00	0.15	0.06
9	09-15-81	0.84	6.00	0.14	0.05
11	10-23-81	0.93	9.00	0.10	0.04
12	10-26-81	0.53	4.67	0.11	0.04
14	11-24-81	0.48	3.00	0.16	0.02
17	01-23-82	0.98	8.00	0.12	0.09
19	02-09-82	0.97	7.00	0.14	0.09
21	03-21-82	1.00	6.00	0.17	0.10
22	03-25-82	0.38	0.50	0.76	0.03
23	03-31-82	0.58	3.67	0.16	0.05
26	04-15-82	0.48	0.50	0.96	0.02
27	04-17-82	0.71	5.67	0.13	0.05
Average		0.70	4.68	0.27	0.05

Table IV-3

Sampled Storms
Central Business District Site (CBD)

Storm	Date	Rainfall (inches)	Duration (hours)	Intensity (in/hr)	Runoff (inches)
1	07-01-81	0.63	0.83	0.76	-
2	08-06-81	0.40	2.50	0.16	0.13
3	08-08-81	0.22	2.00	0.11	0.07
5	08-16-81	0.21	0.33	0.63	0.05
6	08-18-81	0.22	3.17	0.07	0.06
7	08-21-81	1.23	8.00	0.15	0.38
11	10-23-81	0.96	8.83	0.11	0.41
12	10-26-81	0.74	4.83	0.15	0.34
13	11-19-81	0.41	2.00	0.21	0.13
14	11-24-81	0.46	5.17	0.09	0.16
15	12-01-81	1.00	15.00	0.07	0.40
17	01-23-82	0.90	13.33	0.07	0.37
19	09-09-82	0.97	9.00	0.11	0.35
20	03-05-82	0.40	3.50	0.11	0.17
21	03-21-82	0.87	7.50	0.12	0.32
22	03-25-82	0.32	1.63	0.20	0.07
23	03-31-82	0.35	3.33	0.11	0.07
24	03-31-82	0.24	0.83	0.29	0.06
25	04-08-82	0.45	4.67	0.10	0.13
Average		0.58	5.08	0.19	0.19

Table IV-4

Sampled Storms
Strip Commercial Site (SC)

Storm	Date	Rainfall (inches)	Duration (hours)	Intensity (in/hr)	Runoff (inches)
2	08-06-81	0.35	2.33	0.15	0.05
3	08-08-81	0.35	5.83	0.06	0.04
4	08-12-81	0.55	3.00	0.18	0.08
6	08-18-81	0.25	2.50	0.10	0.02
7	08-21-81	1.41	11.00	0.13	0.21
11	10-23-81	0.91	8.50	0.11	0.16
12	10-26-81	0.58	5.50	0.11	0.11
14	11-24-81	0.48	5.17	0.09	0.07
15	12-01-81	1.20	14.00	0.09	0.23
17	01-23-82	0.98	10.00	0.10	0.20
19	02-09-82	1.00	10.00	0.10	0.21
21	03-21-82	1.00	6.67	0.15	0.18
22	03-25-82	0.33	1.00	0.33	0.07
23	03-31-82	0.58	3.67	0.16	0.10
25	04-08-82	0.30	5.50	0.05	0.05
26	04-15-82	0.58	2.50	0.23	0.07
27	04-17-82	0.80	5.00	0.16	0.16
Average		0.68	6.01	0.13	0.12

Table IV-5

Rainfall for Upper and Lower Sink Sites
Water Year 1981

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	0.0	0.0	0.0	0.0	1.17	0.02	0.0	0.02	0.17	0.93	0.0	0.53
2	0.0	0.0	0.0	0.0	0.23	0.0	0.0	0.0	0.0	0.0	0.73	0.0
3	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.55
4	0.0	0.28	0.0	0.0	0.0	0.66	0.40	0.02	0.22	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.18	0.72	0.0	0.0	0.50	0.0	0.0
6	0.0	0.0	0.0	0.20	0.0	0.0	0.0	0.08	2.39	0.02	0.42	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.11	0.20	0.91
8	0.0	0.0	0.0	0.0	0.21	0.0	0.0	0.0	0.0	0.0	0.20	0.0
9	0.0	0.0	1.38	0.0	0.0	0.0	0.40	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.97	0.0	0.0	0.22	0.38	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.16	0.0	0.0	0.03	0.0	0.0	0.23	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.14	0.0
14	0.0	0.020	0.0	0.0	0.0	0.0	0.06	0.0	0.0	0.0	0.0	0.0
15	0.0	0.78	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.26	0.03	2.28
16	0.0	0.0	0.0	0.0	0.0	0.08	0.0	0.0	0.0	0.48	0.12	0.0
17	0.0	0.83	0.0	0.0	0.38	0.06	0.70	0.0	0.0	0.0	0.0	0.0
18	0.0	0.02	0.0	0.0	0.30	0.0	0.20	0.20	0.0	0.0	0.30	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.33	0.16	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.26	0.06	0.0	0.52	0.0	0.49	0.69	0.51	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
22	0.0	0.0	0.0	0.0	0.19	0.68	0.16	0.0	0.0	0.0	0.0	0.0
23	0.0	0.42	0.0	0.0	0.03	0.0	0.08	0.0	0.14	0.0	0.0	0.0
24	0.24	0.62	0.45	0.0	0.0	0.0	0.0	0.0	0.04	0.0	0.0	0.0
25	0.44	0.0	0.0	0.0	0.0	0.0	0.0	0.13	0.0	0.0	0.0	0.0
26	0.0	0.09	0.0	0.0	0.0	0.0	0.0	0.19	0.61	0.0	0.0	0.0
27	0.20	0.43	0.0	0.13	0.0	0.0	0.0	0.86	0.48	0.0	0.0	0.0
28	0.030	0.0	0.0	0.0	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	0.08	0.10	0.0	0.0	0.06	0.0	0.0
30	0.0	0.0	0.05	0.32	0.0	1.14	0.0	0.62	0.0	1.80	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.19	0.0	0.0	0.0	0.0
Total	0.91	3.51	1.88	0.91	3.76	2.90	3.67	2.72	4.92	4.85	3.90	4.27

TOTAL FOR WATER YEAR = 38.20

Table IV-6

Observed Runoff in Inches for Upper Sink Watershed
Water Year 1981

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	0.0	0.0	0.0	0.0	0.014	0.0	0.0	0.0	0.0	0.020	0.0	0.004
2	0.0	0.0	0.0	0.0	0.024	0.0	0.0	0.0	0.023	0.0	0.003	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.019
4	0.0	0.00	0.0	0.0	0.0	0.004	0.001	0.0	0.010	0.0	0.0	0.001
5	0.0	0.0	0.0	0.0	0.0	0.0	0.027	0.0	0.0	0.004	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.282	0.0	0.003	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.062	0.0	0.0	0.033
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.027	0.0	0.001	0.0
9	0.0	0.0	0.010	0.0	0.057	0.0	0.007	0.0	0.016	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.009	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.006	0.0	0.070
16	0.0	0.0	0.0	0.0	0.003	0.0	0.0	0.0	0.0	0.006	0.0	0.0
17	0.0	0.0	0.0	0.0	0.001	0.0	0.013	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.007	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.010	0.001	0.010	0.013	0.010	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.030	0.0
22	0.0	0.0	0.0	0.0	0.0	0.004	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.009	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.006	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.027	0.109	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.019	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.030	0.0	0.010	0.0	0.167	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	0.010	0.0	0.099	0.038	0.059	0.047	0.583	0.216	0.047	0.127

TOTAL FOR WATER YEAR = 1.226

Table IV-7

Observed Runoff in Inches for Lower Sink Watershed
Water Year 1981

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	0.0	0.0	0.0	0.0	0.005	0.0	0.0	0.0	0.0	0.038	0.0	0.0
2	0.0	0.0	0.0	0.0	0.005	0.0	0.0	0.0	0.045	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.001	0.0	0.0	0.005
4	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.006	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.001
6	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.51	0.0	0.0	0.040
7	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.020	0.0	0.0	0.001
8	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.001
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001
12	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.001
13	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.0	0.001	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.090
16	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.004
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.003
18	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.001	0.0	0.001	0.0	0.002
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.0	0.001	0.0	0.002
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.003	0.025	0.001	0.002
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.001	0.001	0.045	0.002
22	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.001	0.001	0.001	0.001	0.002
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.001	0.001	0.001	0.002
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.001	0.001	0.0	0.002
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.001	0.001	0.001	0.001
26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.026	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.012	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.0	0.0
Total	0.0	0.0	0.0	0.0	0.022	0.0	0.0	0.046	0.600	0.073	0.049	0.164

TOTAL FOR WATER YEAR = 0.954

Table IV-8

Rainfall for Upper and Lower Sink Sites
Water Year 1982

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	0.40	0.0	0.77	0.0	0.0	0.0	0.0	0.0	0.15	0.0	0.0	2.23
2	0.0	0.0	0.0	0.43	0.78	0.0	0.0	0.0	0.0	0.0	0.0	0.40
3	0.0	0.0	0.0	1.43	0.44	0.0	0.0	0.0	0.0	0.81	0.0	0.0
4	0.0	0.0	0.03	0.58	0.0	0.02	0.0	0.0	0.23	0.16	0.0	0.0
5	0.21	0.26	0.0	0.0	0.0	0.20	0.0	0.0	0.01	0.0	0.03	0.0
6	0.04	0.0	0.0	0.0	0.16	0.82	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.06	0.0	0.72	0.0	0.36	0.0	0.0	0.20	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.40	0.04	0.0	0.23	0.20	0.0
9	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.01	1.10	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0
12	0.0	0.0	0.0	0.18	0.36	0.0	0.0	0.0	0.44	0.0	0.0	0.0
13	0.0	0.0	0.0	0.20	0.04	0.20	0.0	0.0	0.17	0.0	0.0	0.0
14	0.0	0.0	0.58	0.13	0.0	0.07	0.13	0.0	0.0	0.0	0.0	0.15
15	0.0	0.0	0.13	0.0	0.23	0.95	0.33	0.0	0.19	0.0	0.0	0.0
16	0.0	0.68	0.0	0.08	0.0	0.04	0.0	0.0	0.69	0.0	0.05	0.0
17	0.0	0.0	0.23	0.0	0.36	0.06	0.82	0.0	0.0	0.0	1.3	0.0
18	0.48	0.0	0.0	0.18	0.34	0.0	0.0	0.09	0.0	0.06	0.0	0.0
19	0.05	0.10	0.0	0.27	0.0	0.08	0.0	0.20	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.62	0.90	0.0	1.13	0.06	0.22	0.0	0.0	0.0	0.01
22	0.0	0.0	0.49	0.37	0.0	0.0	0.0	0.52	0.59	0.41	0.0	0.0
23	1.0	0.37	0.22	0.70	0.0	0.0	0.0	0.34	0.0	0.0	0.30	0.0
24	0.0	0.12	0.05	0.0	0.0	0.0	0.0	0.0	0.0	0.22	0.04	0.0
25	0.82	0.0	0.24	0.0	0.0	0.30	0.69	0.0	0.0	0.32	0.0	0.0
26	1.0	0.0	0.0	0.0	0.13	0.0	0.23	0.0	0.50	0.20	0.0	0.26
27	0.02	0.90	0.04	0.0	0.74	0.0	0.0	0.70	0.54	0.0	0.0	0.71
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.80	0.0	0.08	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.46	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.10	0.0
31	0.0	0.0	0.81	0.67	0.0	0.83	0.0	0.0	0.0	4.17	0.39	0.0
Total	4.11	2.89	4.21	6.47	4.63	5.42	2.66	3.27	3.51	9.44	3.77	3.76

TOTAL FOR WATER YEAR = 54.14

Table IV-9

Observed Runoff in Inches for Upper Sink Watershed
Water Year 1982

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	0.001	0.0	0.067	0.0	0.0	0.0	0.007	0.0	0.001	0.0	0.113	0.059
2	0.0	0.0	0.004	0.007	0.037	0.0	0.0	0.0	0.0	0.0	0.009	0.12
3	0.0	0.0	0.0	0.123	0.046	0.0	0.0	0.0	0.0	0.016	0.0	0.032
4	0.0	0.0	0.0	0.189	0.0	0.0	0.0	0.0	0.0	0.011	0.0	0.0
5	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.042	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.083	0.0	0.001	0.0	0.0	0.001	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.014	0.0
9	0.0	0.0	0.0	0.0	0.060	0.0	0.0	0.0	0.0	0.0	0.047	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.067	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.003	0.0	0.0	0.001
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.001
14	0.0	0.0	0.004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.004
15	0.0	0.0	0.0	0.0	0.011	0.093	0.007	0.0	0.0	0.0	0.0	0.0
16	0.0	0.006	0.0	0.0	0.134	0.0	0.0	0.0	0.022	0.0	0.0	0.0
17	0.0	0.0	0.004	0.0	0.0	0.0	0.024	0.0	0.0	0.0	0.129	0.0
18	0.001	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.001	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.142	0.0	0.089	0.0	0.001	0.0	0.0	0.0	0.0
22	0.0	0.0	0.014	0.027	0.0	0.0	0.0	0.017	0.011	0.001	0.0	0.0
23	0.014	0.004	0.030	0.110	0.0	0.0	0.0	0.009	0.0	0.0	0.003	0.0
24	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.004	0.0	0.0
25	0.020	0.0	0.003	0.0	0.0	0.013	0.009	0.0	0.0	0.006	0.0	0.006
26	0.042	0.0	0.0	0.0	0.0	0.0	0.007	0.0	0.011	0.003	0.0	0.001
27	0.004	0.027	0.0	0.0	0.026	0.0	0.0	0.017	0.020	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.022	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.039	0.0	0.0
31	0.0	0.0	0.024	0.020	0.0	0.026	0.0	0.0	0.0	0.891	0.006	0.0
Total	0.082	0.049	0.150	0.632	0.315	0.345	0.055	0.067	0.069	1.038	0.323	0.224

TOTAL FOR WATER YEAR = 3.35

Table IV-10

Observed Runoff in Inches for Lower Sink Watershed
Water Year 1982

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	0.0	0.0	0.077	0.0097	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.070
2	0.0	0.0	0.0	0.0078	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.052
3	0.0	0.0	0.001	0.080	0.048	0.0	0.001	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.045	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.001	0.0	0.0	0.001	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.001	0.0	0.03	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.095	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.001	0.074	0.0	0.001	0.0	0.0	0.001	0.028	0.0
10	0.0	0.0	0.0	0.001	0.0	0.0	0.001	0.0	0.0	0.001	0.0	0.0
11	0.0	0.0	0.0	0.0	0.001	0.0	0.001	0.0	0.0	0.092	0.001	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.001	0.0
13	0.001	0.0	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.002	0.0
14	0.0	0.0	0.0	0.001	0.0	0.001	0.001	0.0	0.0	0.0	0.001	0.0
15	0.0	0.0	0.0	0.001	0.0	0.085	0.001	0.0	0.0	0.0	0.001	0.0
16	0.0	0.0	0.0	0.0	0.183	0.0	0.001	0.0	0.0	0.0	0.001	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.033	0.0	0.0	0.0	0.163	0.0
18	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.001	0.0
19	0.0	0.0	0.0	0.0	0.028	0.0	0.001	0.0	0.0	0.001	0.001	0.0
20	0.0	0.0	0.0	0.020	0.0	0.001	0.0	0.0	0.0	0.001	0.001	0.0
21	0.0	0.0	0.0	0.207	0.0	0.130	0.0	0.0	0.0	0.001	0.001	0.0
22	0.0	0.0	0.001	0.0	0.0	0.001	0.0	0.0	0.0	0.001	0.001	0.0
23	0.0	0.0	0.015	0.172	0.0	0.001	0.0	0.0	0.0	0.0	0.001	0.0
24	0.0	0.0	0.0	0.061	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.0
25	0.019	0.0	0.0	0.0	0.0	0.007	0.0	0.0	0.0	0.0	0.001	0.0
26	0.037	0.0	0.0	0.0	0.0	0.001	0.0	0.0	0.0	0.0	0.001	0.0
27	0.003	0.021	0.0	0.0	0.001	0.001	0.0	0.0	0.008	0.0	0.001	0.0
28	0.0	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.0
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.001	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.047	0.001	0.0
31	0.0	0.0	0.006	0.014	0.0	0.022	0.0	0.0	0.0	1.170	0.001	0.0
Total	0.060	0.022	0.100	0.614	0.395	0.359	0.044	0.0	0.008	1.315	0.212	0.122

TOTAL FOR WATER YEAR = 3.251

from the National Center located in Asheville, North Carolina. The SYNOP rainfall data analysis program (Lystrom, 1976) was used to summarize and statistically characterize the Knoxville rainfall data. Hourly rainfall data for the 27-year period 1952-1978 was analyzed to obtain information on storm events. Each storm event was characterized by an associated attribute of volume (V, inches), duration (D, hours), average intensity (I = V/D, inches/hour) and time since the previous storm (Δ, hours) measured from the midpoint of the successive storms. The minimum number of hours without rainfall between the cessation of a storm and the onset of another storm (used to determine when a storm begins and ends) was six hours.

The mean and coefficient of variation of each of the storm attributes (storm intensity, duration, unit volume and time between storms) were determined by the program. The storm intensities and storm volumes which were shown in tables IV-1 through IV-4 are compared with corresponding attributes of the historic data determined by SYNOP in the following section.

Table IV-11 summarizes the storm rainfall statistics produced by program SYNOP. This analysis includes all rain events defined as a storm by the program. Many small events are identified as storms in this analysis since an isolated rainfall of 0.01 inch occurring in a one-hour period would be defined as a "storm."

Table IV-11

Summary of SYNOP Analyses
Knoxville Airport Data

1952-1978

Measure	Value
Storm rainfall volume, inches	
Average	0.40
Maximum	6.23
Minimum	0.01
Highest month average (December)	0.51
Lowest month average (August)	0.31
Number of Storms	
Average per year	118
Average high month (March)	11
Average low month (October)	7
Intensity, inches per hour	
Average	0.065
Maximum	1.26
Minimum	0.003
Duration, hours	
Average	6.73
Maximum	62
Minimum	1
Time between storms (Δ), hours	
Average	74
Maximum	781.5
Minimum	7[a]

[a] Defined by input of 6-hour minimum of no rain to determine time between storms.

Figures IV-1 and IV-2 show the probability of occurrence of storm volume and the probability of occurrence of storm intensity obtained from the SYNOP analyses. The figures show the percent of time a particular rainfall volume was equaled or exceeded and the percent of time a particular intensity was equaled or exceeded.

C. Comparison of Project Data With the Historic Rainfall Data

Tables IV-1 through IV-4 present storm rainfall data for the four study watersheds. The average storm rainfall volume for those storms in which water quality samples were collected from the four areas was about 0.7 inch. This average is higher than the average of 0.4 inch at the airport gage shown in table IV-11; however, as noted, many small storm events were included in the SYNOP analysis while during the study period (≈one year) very few small storms occurred in the study area. Figure IV-1 indicates that the average storm rainfall volume measured at the study sites equals or exceeds the magnitude of storms which occur about 80 percent of the time at the airport. The largest storm which was included in the water quality associated project data totaled 1.5 inches, and figure IV-1 indicates that only about 5 percent of the storms measured at the airport equal or exceed this value.

The smallest storms included in the water quality associated project data are about 0.2 inch. Figure IV-1 shows that a storm of this size equals or exceeds about 50 percent of those

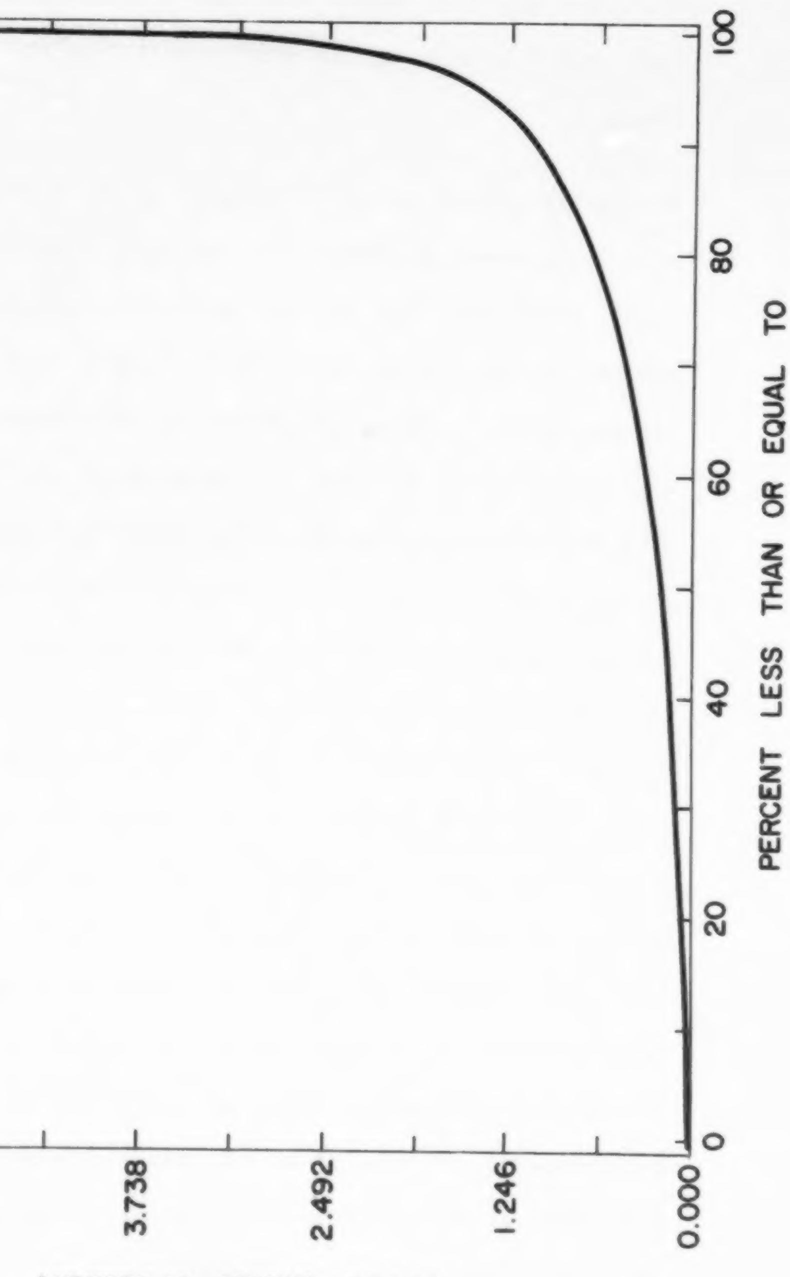

FIGURE IV-1. PROBABILITY OF OCCURRENCES OF STORM VOLUME.

measured at the airport. However, out of all storms that occurred during the study period (including those not sampled for water quality), those less than 0.2 inches contributed less than 2 percent of the total runoff from the four study areas.

The average storm intensity measured at the four Knoxville study watersheds was about 0.2 inch/hour. This intensity equals or exceeds that for storms which occur almost 95 percent of the time at the airport (figure IV-2). The most intense storm of the water quality associated project data occurred on April 15, 1982 and amounted to 0.96 inch per hour. This intensity was equalled or exceeded less than one percent of the time at the airport. The minimum intensity for any of the recorded storms was 0.06 inch per hour and this equalled or exceeded about 65 percent of the airport storms. The percentage of total runoff for the study period contributed by those storms with intensities less than 0.06 inches per hour, however, was only 0.4 percent for all storms that occurred during the study period. This analysis suggests that the historical rainfall data from the Knoxville airport may not be representative of climatic conditions within the study area, or that rainfall during the study period may not have been representative of historical rainfall in the study area. Additional rainfall data within the study area would be required to understand these conditions.

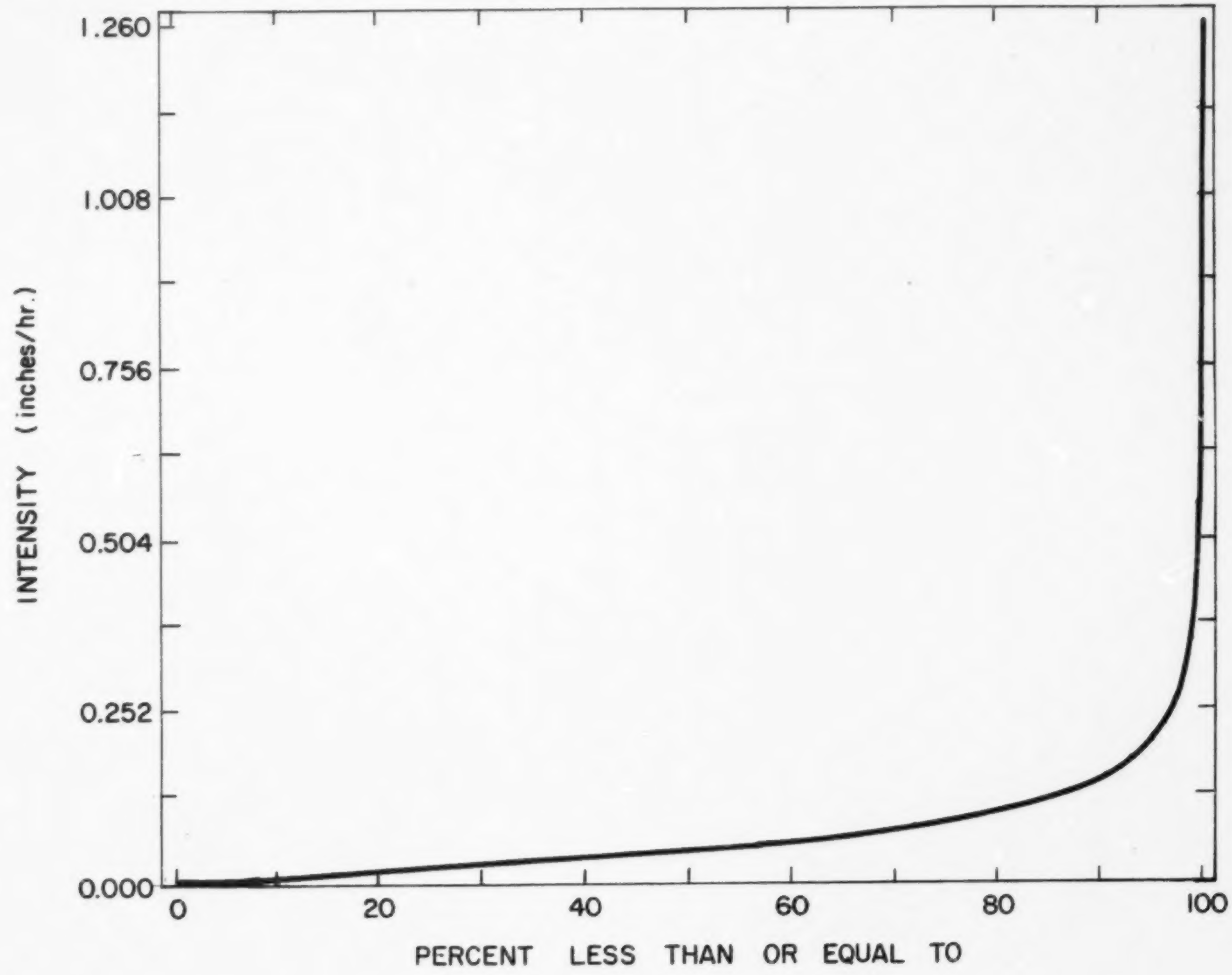

FIGURE IV-2. PROBABILITY OF OCCURRENCES OF STORM INTENSITY.

V. Runoff Water Quality Data

A. Baseflow Water Quality Characteristics

As previously discussed in Section III, a sustained baseflow existed at the CBD and SC sampling sites. Samples of these baseflows were characterized in order to determine the contribution of the baseflow load to the storm related runoff loading at these sites. Table V-1 gives the mean concentrations and loading rates for the baseflow at the CBD and SC sites. The average baseflow at the CBD and SC sites was, respectively, 0.05 and 0.04 cfs. Baseflow loads were calculated for each storm in which runoff samples were collected for water quality analysis, by multiplying the average baseflow concentration by the product of the average baseflow rate and the duration of the runoff sampling. Baseflow loads generally contributed too large of a percentage of storm-related runoff loads at the CBD and SC sites to be ignored. Consequently, when storm event runoff loading calculations were performed with data from the CBD and SC sites, baseflow loads were subtracted out of the total load at these sites (i.e., runoff load = total storm load - baseflow load).

B. Storm Event Runoff Water Quality Characteristics

Section III contained a discussion of the flow proportional composite and discrete sampling that was performed at the R1, R2, CBD, and SC sites to obtain samples as nearly representative as possible of the total storm runoff event. Data generated as

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Table V-1

Mean Concentrations and Loading Rates for the Baseflow at the CBD and SC Sites

	CBD		SC	
Constituent	Mean	Load (lbs/day)	Mean	Load (lbs/day)
pH	-	-	7.7 SU	-
TDS	205 mg/L	55.32	236.7 mg/L	51.10
TSS	25.5 mg/L	6.88	4 mg/L	0.86
NO_2+NO_3	0.74 mg/L	0.20	1.45 mg/L	0.31
NH_3+NH_4	0.21 mg/L	0.06	0.17 mg/L	0.04
TKN	0.91 mg/L	0.25	0.44 mg/L	0.09
DKN	-	-	0.38 mg/L	0.08
TP	0.20 mg/L	0.05	1.50 mg/L	0.32
DP	0.10 mg/L	0.03	1.30 mg/L	0.28
SOC	18.40 mg/L	4.97	10.70 mg/L	2.31
TOC	21.35 mg/L	5.76	15.71 mg/L	3.32
COD	41.50 mg/L	11.20	49.00 mg/L	10.58
BOD_5	10 mg/L	2.70	-	-
Al	76 mg/L	20.51	110 mg/L	23.75
SO_4	43 mg/L	11.60	37.33 mg/L	8.06
Cl	26 mg/L	7.02	21.33 mg/L	4.61
Ca	36.15 mg/L	9.75	35.17 mg/L	7.59
Mg	6.91 mg/L	1.86	6.15 mg/L	1.33
Na	21.30 mg/L	5.75	26.53 mg/L	5.73
K	2.69 mg/L	0.73	6.17 mg/L	1.33
Cu	23.50 μg/L	0.0063	-	-
Zn	188 μg/L	0.0507	<5 μg/L	-
Cr	611.50 μg/L	0.1650	-	-
Se	<1 μg/L	-	<1 μg/L	-
Hg	<0.2 μg/L	-	<0.2 μg/L	-
Ni	<100 μg/L	-	<100 μg/L	-
Cd	0.95 μg/L	0.0003	0.63 μg/L	0.0001
Pb	45.50 μg/L	0.0123	12.33 μg/L	0.0027
Fe	491.50 μg/L	0.1326	386.67 μg/L	0.0835
Mn	41.0 μg/L	0.0111	51.67 μg/L	0.0112

a result of the analysis of these samples consists of a single concentration value for each constituent analyzed in the composite samples and multiple concentration values over the hydrograph for the discrete samples. These data are listed in Appendix E. Because of the proportional sample collection, the concentrations of constituents measured in the composite samples can be considered the mean concentrations of the runoff event or, the event mean concentration (EMC).

Mathematically, the EMC can be defined as the total constituent mass contained in the runoff from a storm event, divided by the total volume of runoff for the event, such that:

$$\text{EMC} = \frac{\text{Mass in runoff}}{\text{Volume of runoff}}$$

It should be pointed out that the true EMC of a composite sample is only approached as the number of aliquotes in a flow-weighted composite sample approaches infinity. Therefore, the composite concentration measured in this study are only approximations of true EMC. However, the collection of infinite aliquotes is impossible; therefore, for this study the approximate EMCs will be treated as the true EMCs.

The EMC for a discrete sample set must be determined by a mathematical integration process. When discrete samples are collected, the only information obtainable are the instantaneous flow rate at successive time increments and instantaneous constituent concentrations at successive time increments. The

EMC cannot be determined simply by calculating the arithmetic average of the discrete concentrations for a storm, or by assuming any one sample is representative of the EMC. The instantaneous data does, however, provide a means of calculating the EMC for discrete samples. For example, a plot of the instantaneous flow rates versus time will produce a storm hydrograph. The area under the hydrograph is equal to the total runoff volume and can be calculated using the trapezoid rule as follows:

$$\text{Total runoff} = q(t)dt \approx \Sigma(t_{n+1}-t_n)\tfrac{1}{2}(q_n+q_{n+1})$$

Where: q = instantaneous flow rate at time t

t = time of instantaneous flow measurement

Similarly, a plot of instantaneous constituent concentration versus time produces a pollutograph, and again using the trapezoid rule, the area under the pollutograph is calculated to give the total constituent load of the storm:

$$\text{Total load} = c(t)q(t)dt \approx \Sigma(t_{n+1}-t)\tfrac{1}{2}(c_n q_n+c_{n+1}q_{n+1})$$

Where c = instantaneous constituent concentration at time t

q = instantaneous flow rate at time t

t = time of instantaneous flow rate and constituent concentration

From the above, the EMC can be calculated for discrete samples as:

$$\text{EMC} = \frac{\text{Total load}}{\text{Total runoff}} = \frac{\Sigma(t_{n+1}-t)\tfrac{1}{2}(c_n q_n+c_{n+1}q_{n+1})}{\Sigma(t_{n+1}-t_n)\tfrac{1}{2}(q_n+q_{n+1})}$$

The event mean concentrations of the constituents measured at the R1, R2, CBD, and SC water quality sampling sites for composite and discrete samples are listed in table V-2.

C. Statistical Analysis

Prior to performing any parametric statistical analysis on the constituent EMCs in table V-2, statistical tests were performed on the data set to determine whether it was normal or log-normal in its distribution. The Shapiro-Wilk goodness-of-fit test was applied to the EMCs in the data set and to the EMCs after their transformation into log space (ln of EMC). The tests' W-statistics were calculated and are presented in table V-3. Values greater than 0.05 indicate the data is log-normal in its distribution. Although several constituents deviate slightly from an indication of a log-normal distribution ($W > 0.05$), generally most of the data conform to a log-normal distribution. Indeed, environmental type data generally tend to follow a log-normal distribution. Additionally, if log-normal data are treated as if they were normal, erroneous estimates of large deviations from the central value can be made. Conversely, if truly normal data are treated as log-normal, the errors will usually be small and conservative. In consideration of these facts, along with the results of the Shapiro-Wilk test, it was concluded that the EMC data could be treated as a log-normal distribution and were amenable to the application of parametric statistics.

Table V-2

Event Mean Concentrations - General Parameters
Knoxville Urban Runoff Study

(Values in mg/L unless otherwise noted)

	CBD																				
											Coliforms[a]										
Storm	TDS	TSS	NO_2+NO_3	NH_3	TKN	DKN	TP	OP	SOC	TOC	COD	Fecal	Strep	BOD	Alk.	SO_4	Cl^-	Ca	Mg	Na	K
2	105.5	246.6	0.52	0.00	1.01	-	0.42	0.11	54.5	60.6	161.6	-	-	32.9	46.9	1.6	0.0	37.1	2.7	0.0	4.3
3	0.0	128.0	0.00	0.00	0.00	-	0.00	0.00	0.0	0.0	37.0	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2
5	0.0	32,914.0	4.67	1.19	0.00	-	8.06	0.00	0.0	0.0	5301.7	-	-	-	0.0	0.0	0.0	611.3	0.0	0.0	43.0
6	0.0	431.9	4.43	0.21	2.58	-	0.80	0.00	0.0	6.9	129.6	-	-	31.5	0.0	0.0	0.0	21.7	0.0	0.0	10.9
7	96.6	110.5	0.86	0.14	0.57	-	0.21	0.05	9.9	11.8	83.1	-	-	6.5	52.0	11.0	0.0	34.4	3.3	0.0	3.1
8	90.3	70.7	0.78	0.01	0.54	-	0.13	0.02	13.0	17.3	68.6	-	-	12.4	30.1	14.0	0.6	21.3	2.3	0.0	2.5
11	48.5	97.4	0.43	0.18	0.38	-	0.13	0.01	5.1	7.8	37.8	-	-	5.5	28.2	7.2	0.0	16.1	1.5	0.0	2.0
12	36.9	111.8	0.20	0.08	0.20	-	0.10	0.00	2.6	5.8	17.7	-	-	-	45.8	2.4	0.0	24.3	2.7	0.0	2.3
13	13.4	139.7	0.64	0.19	0.51	-	0.26	0.02	0.9	3.6	57.5	-	-	7.3	7.0	0.0	0.0	22.4	1.5	0.0	2.2
14	1.3	58.5	1.02	0.29	0.60	-	0.18	0.01	0.4	11.0	71.7	-	-	12.8	5.7	2.2	0.0	5.8	0.0	0.0	2.0
15	29.7	40.8	0.25	0.07	0.31	-	0.08	0.00	2.6	7.6	35.2	-	-	10.0	18.3	3.4	0.0	8.1	0.4	0.0	1.6
17	90.8	139.1	0.35	0.13	0.61	-	0.20	0.00	8.1	15.2	91.1	-	-	14.5	42.8	-	-	21.1	2.5	-	-
18	57.0	54.5	0.42	0.17	0.52	-	0.13	0.03	4.8	11.1	60.6	-	-	18.7	21.2	-	-	11.8	0.9	-	-
20	54.7	441.5	0.79	0.19	0.37	-	0.30	0.00	2.0	11.3	117.3	-	-	12.7	39.1	-	-	72.8	10.1	-	-
21	14.5	29.1	0.22	0.05	0.16	-	0.04	-	-	9.9	28.7	-	-	10.5	20.7	-	-	-	-	-	-
23	110.8	86.3	0.19	0.00	0.20	-	0.20	0.08	5.7	10.4	210.0	-	-	23.6	0.0	-	-	20.4	0.0	-	-
24	0.0	494.7	0.00	0.00	0.00	-	0.16	-	-	0.0	198.1	-	-	20.8	0.0	-	-	-	-	-	-
25	7.5	91.6	0.26	0.17	0.88	-	0.29	-	-	7.9	115.4	-	-	-	16.0	-	-	-	-	-	-
27	37.1	133.7	0.47	0.02	0.70	-	0.20	-	-	8.6	63.5	-	-	-	30.3	-	-	-	-	-	-

a. Number organisms per 100 ml

Table V-2

(Continued)

Event Mean Concentrations - General Parameters
Knoxville Urban Runoff Study

(Values in mg/L unless otherwise noted).

R1

												Coliforms[a]									
Storm	TDS	TSS	NO_2+NO_3	NH_3	TKN	DKN	TP	OP	SOC	TOC	COD	Fecal	Strep	BOD	Alk.	SO_4	Cl^-	Ca	Mg	Na	K
1	140.0	42.0	0.58	0.20	1.4	0.72	1.0	0.18	6.2	16.0	63.0	2,200	2,000	12.9	20.0	17.0	1.0	35.7	4.6	0.4	2.7
2	110.0	250.0	0.80	0.04	0.6	0.64	0.5	0.23	25.0	27.0	63.0	200,000	20,000	16.0	32.0	13.0	3.0	17.2	2.2	1.6	6.1
7	80.0	470.0	0.99	0.08	0.7	0.30	0.5	0.13	5.3	11.0	87.0	23,000	280,000	4.8	37.0	12.0	1.0	21.7	3.2	0.4	4.3
8	110.0	560.0	0.72	0.09	0.8	0.36	0.6	0.13	11.0	40.0	140.0	260,000	440,000	12.0	45.0	12.0	1.0	31.6	4.6	0.5	4.0
9	105.5	1100.0	0.09	0.14	1.4	0.22	0.8	0.06	5.1	5.9	10.0	90,000	450,000	9.0	58.0	3.7	1.0	54.1	9.4	0.3	2.9
11	90.0	170.0	0.54	0.05	1.2	0.36	0.5	0.20	28.0	42.0	100.0	13,000	46,000	33.0	37.0	10.0	3.0	16.9	1.9	1.3	9.4
12	90.0	730.0	0.45	0.04	1.7	0.28	1.2	0.10	13.0	31.0	93.0	20,000	160,000	-	56.0	4.0	2.0	36.7	5.4	0.6	5.9
13	173.5	1089.5	0.42	0.24	3.5	0.61	1.7	0.21	36.4	73.7	497.2	49,685	155,753	63.2	54.9	9.4	4.9	51.5	6.9	2.0	6.1
14	90.0	180.0	0.76	0.12	1.0	0.60	0.5	0.19	17.0	41.0	110.0	10,000	71,000	27.0	35.0	10.0	2.0	13.2	1.6	0.8	6.0
15	89.6	196.7	0.22	0.04	0.6	0.17	0.3	0.10	10.1	16.2	71.8	5,381	58,289	10.9	28.7	1.4	2.5	12.1	1.5	0.5	3.8
16	90.0	710.0	0.46	0.25	1.2	0.36	0.7	0.03	10.0	31.0	200.0	650	84,000	-	59.0	-	-	35.0	6.2	-	-
17	110.0	450.0	0.27	0.17	0.7	0.08	0.3	0.02	11.0	31.0	120.0	875	58,000	3.5	43.0	-	-	20.0	3.7	-	-
19	180.0	1000.0	0.27	0.13	1.5	0.28	0.7	0.09	9.8	33.0	180.0	1,100	12,000	6.6	36.0	-	-	3.2	5.6	-	-
21	78.0	305.4	0.15	0.09	0.7	-	0.3	-	-	15.2	78.8	13,437	-	9.0	34.8	-	-	-	-	-	-
27	67.4	919.7	0.28	0.03	5.1	-	1.4	-	-	23.2	239.5	78,505	-	-	59.7	-	-	-	-	-	-

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a. Number organisms per 100 ml

Table V-2

(Continued)

Event Mean Concentrations - General Parameters
Knoxville Urban Runoff Study

(Values in mg/L unless otherwise noted)

R2												Coliforms[a]									
Storm	TDS	TSS	NO_2+NO_3	NH_3	TKN	DKN	TP	OP	SOC	TOC	COD	Fecal	Strep	BOD	Alk.	SO_4	Cl^-	Ca	Mg	Na	K
1	52.0	800.0	0.41	0.14	0.3	0.32	0.1	0.05	5.0	8.7	35.0	1,800	2,000	9.9	50.0	6.0	1.0	11.8	1.0	0.3	1.4
2	100.0	23.0	0.67	0.03	0.9	0.46	0.3	0.24	5.1	6.1	46.0	14,000	20,000	16.0	38.0	8.0	9.0	19.4	1.8	2.3	2.4
4	72.0	5.0	0.68	0.02	0.6	0.54	0.3	0.16	5.5	10.0	69.0	860,000	34,000	14.0	23.0	14.0	3.0	20.9	1.7	1.4	1.9
7	40.0	18.0	0.22	0.07	0.3	0.30	0.1	0.10	3.4	4.4	25.0	10,000	18,000	8.0	28.0	4.0	1.0	11.6	0.9	0.4	1.2
8	58.0	47.0	0.62	0.06	0.4	0.25	0.2	0.14	6.8	8.8	38.0	9,000	420,000	6.2	45.0	8.0	1.0	13.5	1.3	0.6	2.2
9	42.0	75.0	0.15	0.04	0.3	0.26	0.2	0.13	5.5	9.8	30.0	10,000	72,000	3.2	32.0	4.0	1.0	12.6	1.4	0.3	2.8
11	45.2	28.8	0.42	0.11	0.2	0.14	0.1	0.10	5.0	7.8	27.9	5,965	21,526	6.4	25.3	6.5	1.4	12.2	1.0	0.6	1.6
12	60.0	46.0	0.15	0.04	0.3	0.14	0.1	0.06	4.5	7.3	25.0	4,000	45,000	-	37.0	4.0	1.0	13.7	1.1	0.5	1.3
17	87.0	71.0	0.16	0.09	0.4	0.10	0.1	0.06	10.0	12.0	57.0	520	36,000	3.3	47.0	-	-	18.0	1.9	-	-
19	70.0	150.0	0.20	0.05	0.4	0.78	0.4	0.31	5.0	11.0	53.0	300	30,000	4.6	25.0	-	-	20.0	2.1	-	-
21	40.0	68.0	0.02	0.02	0.4	0.38	0.1	0.08	5.3	9.4	43.0	2,800	400,000	5.7	39.0	-	-	22.0	1.8	-	-
22	71.3	320.6	0.49	0.31	0.8	-	0.5	-	-	30.5	149.3	461	-	-	52.0	-	-	-	-	-	-
23	70.0	62.0	0.36	0.15	0.5	0.54	0.3	0.11	12.0	16.0	72.0	100	9,000	15.0	26.0	-	-	25.0	1.7	-	-
26	80.7	181.0	0.45	0.11	1.4	-	0.5	-	-	14.3	101.8	4,638	-	-	40.2	-	-	-	-	-	-
27	39.7	45.1	0.30	0.10	0.6	-	0.2	-	-	10.8	47.2	5,430	-	-	32.1	-	-	-	-	-	-

a. Number organisms per 100 ml

Table V-2

(Continued)

Event Mean Concentrations - General Parameters
Knoxville Urban Runoff Study

(Values in mg/L unless otherwise noted)

SC																					
												Coliforms^a									
Storm	TDS	TSS	NO_2+NO_3	NH_3	TKN	DKN	TP	OP	SOC	TOC	COD	Fecal	Strep	BOD	Alk.	SO_4	Cl^-	Ca	Mg	Na	K
2	81.8	83.5	0.56	0.41	1.0	1.01	0.5	0.34	20.2	24.5	97.4	-	-	-	29.6	7.8	1.1	21.9	1.7	0.0	1.8
4	64.1	3.8	0.64	0.02	0.5	0.25	0.3	0.09	5.8	9.5	84.3	-	-	-	14.9	12.1	1.5	25.9	2.3	0.0	1.4
7	58.2	51.8	0.95	0.04	0.3	0.39	0.1	0.11	5.9	8.1	15.9	-	-	-	0.0	4.2	1.6	16.3	1.3	0.0	0.9
9	13.4	27.4	0.10	0.13	0.2	0.27	0.0	0.00	4.1	4.9	7.7	-	-	-	26.1	2.0	0.0	13.1	1.2	0.0	0.7
11	39.4	29.9	0.31	0.22	0.5	0.29	0.1	0.07	8.4	10.9	41.2	-	-	-	21.3	6.1	1.4	12.1	0.9	0.0	0.8
12	49.8	36.8	0.15	0.14	0.4	0.25	0.1	0.02	4.5	5.5	19.7	-	-	-	23.8	4.6	0.0	21.4	1.4	0.0	1.1
17	77.8	111.9	0.50	0.15	0.4	0.30	0.1	0.00	5.7	9.2	78.6	-	-	-	40.8	-	-	20.0	2.6	-	-
19	51.9	148.0	0.25	0.16	0.3	0.25	0.0	0.00	4.1	9.5	63.4	-	-	-	26.2	-	-	28.5	3.2	-	-
21	17.9	107.4	0.00	0.05	0.7	0.33	0.5	0.13	4.9	14.2	88.1	-	-	-	37.5	-	-	24.3	2.0	-	-
22	72.2	805.3	0.20	0.43	1.7	-	1.1	-	-	13.4	311.2	-	-	-	51.5	-	-	-	-	-	-
23	64.1	111.8	0.23	0.84	2.2	1.95	1.1	0.89	13.5	17.5	91.3	-	-	-	23.7	-	-	22.7	2.5	-	-
26	108.8	219.4	0.37	0.32	1.9	-	1.1	-	-	19.5	120.9	-	-	-	45.3	-	-	-	-	-	-
27	31.0	48.8	0.20	0.07	0.5	-	0.1	-	-	10.8	41.2	-	-	-	26.7	-	-	-	-	-	-

a. Number of organisms per 100 ml

Table V-2a

Event Mean Concentrations (μg/L) Metals
Knoxville Urban Runoff Study

	CBD									
Storm	Total copper	Total zinc	Total chromium	Total selenium	Total mercury	Total nickel	Total cadmium	Total lead	Total iron	Total manganese
2	73.23	686.9	134.83	1	0.20	23.49	1.94	358.4	7,487	270.5
3	48.75	185.0	0.00	1	0.20	0.00	1.09	177.7	6,339	165.8
5	3612.23	29,586.1	0.00	1	10.03	0.00	64.85	21,135.5	493,918	15,379.1
6	90.16	1,370.8	0.00	1	0.20	0.00	3.31	789.9	20,353	574.3
7	32.05	280.4	0.00	1	0.20	42.97	0.66	141.9	3,894	120.8
8	32.55	279.7	65.69	1	0.20	39.66	0.78	135.4	2,360	94.1
11	21.64	203.8	0.00	1	0.20	43.59	0.75	95.3	2,258	69.9
12	11.33	193.8	0.00	-	0.20	-	0.89	131.8	3,121	103.6
13	24.27	312.1	0.00	-	0.35	-	0.72	142.8	6,390	166.7
14	22.80	217.5	0.00	-	0.20	-	0.59	79.9	2,582	78.9
15	16.15	124.7	0.00	-	0.20	-	0.44	67.5	1,292	43.3
17	54.90	322.7	0.00	-	-	-	1.34	193.4	6,610	211.1
19	36.74	236.4	0.00	-	-	-	1.12	108.3	2,805	90.5
20	69.26	641.6	0.00	-	0.33	-	4.29	488.8	12,525	643.5
21	81.04	110.4	0.00	-	0.20	-	0.59	46.7	1,613	40.3
23	51.74	345.5	0.00	-	-	-	0.52	224.4	4,271	210.4
24	219.97	806.3	0.00	-	0.91	-	4.04	817.6	13,225	291.6
25	152.82	385.7	0.00	-	0.20	-	0.80	210.4	3,947	175.8
27	48.82	265.3	0.00	-	0.21	-	0.93	215.7	3,739	175.5

Table V-2a

(Continued)

Event Mean Concentrations (µg/L) Metals
Knoxville Urban Runoff Study

	R1																					
	Copper		Zinc		Chromium		Selenium		Mercury		Nickel		Cadmium		Lead		Iron		Manganese		Aluminum	
Storm	Total	Dis.	Total	Dis.	Total	Dis.	Total	Dis.	Total	Dis.	Total	Dis.	Total	Dis.	Total	Dis.	Total	Dis.	Total	Dis.	Total	Dis.
1	48.00	-	377.00	-	5.00	-	1	-	0.20	-	100	-	1.90	-	420.00	-	2,720.0	-	841.00	-	-	-
2	38.00	-	218.00	-	13.00	-	1	-	0.20	-	50	-	1.20	-	180.00	-	9,800.0	-	264.00	-	-	-
7	28.00	-	302.00	-	6.00	-	1	-	0.20	-	50	-	0.80	-	300.00	-	11,000.0	-	480.00	-	5,860.0	-
8	58.00	-	434.00	-	17.00	-	1	-	0.30	-	50	-	1.20	-	470.00	-	12,900.0	-	764.00	-	-	-
9	92.00	1	772.00	5	13.00	2	1	1	0.50	0.2	50	50	2.70	0.2	750.00	2	17,200.0	245	1550.00	5	-	-
11	22.00	-	191.00	-	4.00	-	1	-	0.20	-	50	-	0.60	-	210.00	-	3,800.0	-	244.00	-	2,460.0	-
12	87.00	-	536.00	-	8.00	-	-	-	0.40	-	-	-	2.60	-	800.00	-	12,800.0	-	941.00	-	8,560.0	-
13	104.79	-	1116.55	-	15.98	-	1	-	1.20	-	50	-	3.59	-	956.66	-	16,958.0	-	1180.72	-	10,204.0	-
14	27.00	-	131.00	-	2.00	-	-	-	0.20	-	-	-	0.60	-	170.00	-	3,980.0	-	218.00	-	1,970.0	-
15	23.91	-	147.40	-	6.55	-	-	-	0.25	-	-	-	0.51	-	181.04	-	5,052.2	-	253.26	-	5,376.8	-
16	93.00	10	600.00	36	270.00	6	-	-	0.20	0.4	-	-	5.00	0.2	600.00	10	29,000.0	188	1260.00	112	10,000.0	50
17	72.00	23	308.00	19	9.00	2	-	-	-	-	-	-	1.00	0.4	280.00	5	19,000.0	110	570.00	25	7,400.0	160
19	100.00	7	600.00	25	33.00	1	-	-	-	-	-	-	3.00	0.3	560.00	1	39,000.0	22	1100.00	4	41,000.0	50
21	63.57	-	236.00	-	3.92	-	-	-	0.22	-	-	-	0.82	-	215.23	-	9,275.5	-	395.26	-	11,113.6	-
27	215.09	-	306.27	-	37.49	-	-	-	0.41	-	-	-	3.13	-	675.58	-	11,323.6	-	481.36	-	27,501.0	-

Table V-2a

(Continued)

Event Mean Concentrations (µg/L) Metals
Knoxville Urban Runoff Study

	R2																					
	Copper		Zinc		Chromium		Selenium		Mercury		Nickel		Cadmium		Lead		Iron		Manganese		Aluminum	
Storm	Total	Dis.	Total	Dis.	Total	Dis.	Total	Dis.	Total	Dis.	Total	Dis.	Total	Dis.	Total	Dis.	Total	Dis.	Total	Dis.	Total	Dis.
1	1.00	-	65.00	-	2.00	-	1	-	0.20	-	100	-	0.50	-	96.00	-	379.00	-	58.00	-	-	-
2	9.00	-	80.00	-	10.00	-	1	-	0.20	-	50	-	0.40	-	89.00	-	982.00	-	57.00	-	-	-
4	37.00	-	166.00	-	9.00	-	1	-	0.20	-	50	-	0.90	-	180.00	-	2320.00	-	104.00	-	-	-
7	9.00	-	30.00	-	3.00	-	1	-	0.20	-	50	-	0.20	-	57.00	-	581.00	-	25.00	-	370.00	-
8	21.00	-	43.00	-	4.00	-	1	-	0.20	-	50	-	0.60	-	98.00	-	1630.00	-	74.00	-	-	-
9	12.00	12	51.00	10	11.00	1	1	1	0.20	0.7	50	50	0.60	0.5	99.00	2	2200.00	125	122.00	5	-	-
11	23.59	-	95.54	-	1.45	-	1	-	0.20	-	50	-	0.41	-	115.33	-	832.54	-	44.01	-	361.05	-
12	9.00	-	85.00	-	3.00	-	-	-	0.20	-	-	-	0.50	-	160.00	-	1260.00	-	64.00	-	760.00	-
17	36.00	9	106.00	18	4.00	1	-	-	-	-	-	-	0.70	0.1	150.00	6	2900.00	82	110.00	10	1200.00	50
19	27.00	8	150.00	19	4.00	1	-	-	-	-	-	-	0.80	0.2	220.00	5	5100.00	67	210.00	7	2600.00	60
21	40.00	20	100.00	30	14.00	1	-	-	0.20	0.2	-	-	0.50	0.1	127.00	20	1800.00	30	110.00	10	1200.00	100
22	70.59	-	358.36	-	9.37	-	-	-	0.24	-	-	-	1.73	-	612.08	-	5447.99	-	388.29	-	4943.80	-
23	40.00	40	120.00	60	2.00	1	-	-	-	-	-	-	0.50	-	170.00	10	2000.00	40	150.00	70	1300.00	100
26	43.11	-	198.34	-	7.96	-	-	-	0.20	-	-	-	1.10	-	280.06	-	4010.38	-	224.97	-	2852.78	-
27	53.99	-	90.49	-	2.26	-	-	-	0.21	-	-	-	0.64	-	87.03	-	2138.47	-	80.88	-	1344.03	-

Table V-2a

(Continued)

Event Mean Concentrations (µg/L) Metals
Knoxville Urban Runoff Study

Storm	SC Total copper	Total zinc	Total chromium	Total selenium	Total mercury	Total nickel	Total cadmium	Total lead	Total iron	Total manganese
2	33.22	283.84	3.74	1	0.20	43.35	1.35	372.11	3,380.3	128.09
4	42.13	271.20	15.85	1	0.20	46.08	1.67	393.36	3,172.1	159.40
7	19.92	132.35	1.85	1	0.20	48.57	0.66	265.13	1,530.0	90.00
9	0.00	74.86	0.00	1	0.20	47.09	1.15	158.34	1,179.8	51.92
11	14.50	114.81	3.86	1	0.21	48.06	1.02	199.93	893.6	51.85
12	28.54	103.66	1.81	-	0.20	-	0.47	206.88	1,284.3	57.01
17	39.78	194.85	12.09	-	-	-	0.83	301.49	3,786.7	138.68
19	34.18	248.63	7.95	-	-	-	1.19	374.75	4,149.3	196.83
21	27.28	146.38	0.32	-	0.20	-	0.92	230.93	2,495.2	112.33
22	120.94	772.40	18.48	-	0.45	-	4.81	2133.86	15,214.5	812.56
23	50.19	213.73	3.51	-	-	-	0.92	416.02	3,587.1	186.94
26	114.83	180.18	7.26	-	0.48	-	1.63	404.41	4,580.2	177.52
27	61.70	110.97	3.05	-	0.29	-	0.70	120.15	1,954.2	86.50

Table V-3

Shapiro-Wilk Goodness-of-Fit Test for Log-Normality

	W-Statistic			
Constituent	CBD	R1	R2	SC
pH	0.17	0.49	<0.01	<0.01
Conductivity	0.46	0.49	0.17	0.25
Total dissolved solids	0.48	0.07	0.49	0.17
Total suspended solids	0.33	0.24	0.49	<0.01
Nitrite plus nitrate	0.66	0.10	0.05	0.21
Ammonia	0.01	0.46	0.60	0.83
Total kjeldahl nitrogen	0.72	0.46	0.26	0.46
Dissolved kjeldahl nitrogen	0.61	0.18	0.56	0.01
Total phosphorus	0.44	0.91	0.10	0.91
Dissolved phosphorus	0.45	0.14	0.76	0.97
Soluble organic carbon	0.03	0.48	0.12	<0.01
Total organic carbon	0.04	0.01	0.78	0.53
Chemical oxygen demand	0.67	<0.01	0.58	0.01
Fecal coliform	0.56	0.42	0.43	0.33
Fecal streptococcus	0.95	0.49	0.48	<0.01
Biochemical oxygen demand	0.79	0.91	0.41	0.97
Alkalinity	0.13	0.32	0.48	<0.01
Sulfate	0.43	0.05	0.21	0.46
Chloride	0.48	0.01	<0.01	0.03
Calcium	0.87	0.06	0.26	0.08
Magnesium	0.74	0.75	0.38	0.37
Sodium	0.82	0.41	0.26	0.70
Potassium	0.80	0.62	0.47	0.48
Copper	0.92	0.46	0.01	<0.01
Zinc	0.46	0.77	0.83	0.55
Chromium	0.49	0.21	0.23	0.03
Selenium	-	-	-	-
Mercury	<0.01	<0.01	-	<0.01
Nickel	<0.01	<0.01	<0.01	<0.01
Cadmium	0.40	0.52	0.09	0.46
Lead	0.92	0.43	0.67	0.36
Iron	0.76	0.51	0.77	0.03
Manganese	0.66	0.37	0.65	0.36
Aluminum	0.39	0.53	0.62	0.40

The attributes of a log-normal distribution are described by the Gaussian distribution of their logarithms. However, the logarithms do not describe the actual data itself. Description of the data is accomplished by the conversion back to the antilogs. The antilog of the mean of a set of logs is the geometric mean, $\bar{X}_g$, where:

$$\bar{X}_g = \text{antilog}\ \frac{(\ln X_1 + \ln X_2 + \cdots \ln X_n)}{n}$$

The standard deviation of a log-normal distribution is calculated the same as for a normal distribution but using the logs of the data. The value of the standard deviation, however, will be in logarithmic form and must be converted back by taking the antilog. The standard deviation of the geometric mean(s) which has been termed the spread factor is calculated as:

$$S = \text{antilog}\ \left[\frac{(\ln X_1 - \ln \bar{X}_g)^2 + (\ln X_2 - \ln X_g)^2 + \cdots (\ln X_n - \ln \bar{X}_g)^2}{(n-1)}\right]^{\frac{1}{2}}$$

In tables V-4 through V-7, the geometric mean, spread factor, and maximum and minimums of the EMCs are presented for all data from the R1, R2, CBD, and SC runoff sampling sites. The SC sampling site was located hydrologically downstream from the R2 basin and measurements and samples taken at SC reflected the additive effects of mixed runoff from the R2 and SC basins. In order to characterize the runoff from just the SC basin, the

Table V-4

Event Mean Concentrations
Summary Statistics
Residential 1 (R1)

Parameter	Max.	Min.	Number of observations	Geometric mean	Spread factor
pH, SU	7.5	6.0	11	–	–
Conductivity, μmhos/cm	160	79	11	–	–
TDS, mg/L	180	67.4	15	102.84	1.32
TSS, mg/L	1,100	42	15	405.27	2.49
NO_2+NO_3-N, mg/L	0.99	0.090	15	0.39	1.94
NH_3+NH_4-N, mg/L	0.25	0.030	15	0.093	2.01
TKN, mg/L	5.16	0.64	15	1.22	1.84
DKN, mg/L	0.72	0.080	13	0.33	1.84
TP, mg/L	1.78	0.35	15	0.69	1.65
DP, mg/L	0.23	0.020	13	0.11	2.14
SOC, mg/L	36.4	5.1	13	12.06	1.85
TOC, mg/L	73.7	5.9	15	24.76	1.87
COD, mg/L	497	10	15	102.47	2.35
Fecal coliform, No./100 ml	260,000	650	15	13,668.80	6.88
Fecal strep, No./100 ml	450,000	2000	13	67,595.50	4.57
BOD_5, mg/L	63.3	3.5	12	12.44	2.27
Total alkalinity, mg/L	60	20	15	40.61	1.37
SO_4, mg/L	17.0	1.4	10	7.58	2.16
Cl, mg/L	5	3	10	1.85	1.70
Ca, mg/L	54.1	3.2	13	21.87	2.13
Mg, mg/L	9.44	1.58	13	3.80	1.79
Na, mg/L	2.01	0.39	10	0.76	1.78
K, mg/L	9.40	2.70	10	4.79	1.47
Cu, total, μg/L	215	22	15	57.80	1.93
Zn, total, μg/L	1,117	131	15	347.81	1.85
Cr, total, μg/L	270	2	15	11.37	3.28
Se, total, μg/L	1	1	7	1.00	1.00
Hg, total, μg/L	1.20	0.20	13	0.29	1.71
Ni, total, μg/L	100	50	7	55.21	1.30
Cd, total, μg/L	5.00	0.52	15	1.49	2.11
Pb, total, μg/L	957	170	15	382.13	1.84
Fe, total, μg/L	39,000	2720	15	10,573.10	2.14
Mn, total, μg/L	1,550	218	19	573.17	1.95
Al, total, μg/L	41,000	1970	11	8,269.53	2.45

Table V-5

Event Mean Concentrations
Summary Statistics
Residential 2 (R2)

Parameter	Max.	Min.	Number of observations	Geometric mean	Spread factor
pH, SU	7.2	5.6	11	-	-
Conductivity, µmhos/cm	160	63	11	-	-
TDS, mg/L	100	40	15	59.22	1.36
TSS, mg/L	800	5	15	62.72	3.40
NO_2+NO_3-N, mg/L	0.68	0.020	15	0.27	2.46
NH_3+NH_4-N, mg/L	0.32	0.020	15	0.70	2.20
TKN, mg/L	1.48	0.26	15	0.51	1.60
DKN, mg/L	0.54	0.10	12	0.26	1.74
TP, mg/L	0.54	0.14	15	0.25	1.57
DP, mg/L	0.31	0.050	12	0.11	1.74
SOC, mg/L	12.0	3.40	12	5.74	1.41
TOC, mg/L	30.5	4.4	15	10.06	1.56
COD, mg/L	149	25	15	47.66	1.67
Fecal coliform, No./100 ml	860,000	100	15	3,615.93	8.31
Fecal strep, No./100 ml	420,000	2000	12	34,443.50	4.35
BOD_5, mg/L	16.0	3.2	11	7.26	1.77
Total alkalinity, mg/L	52	23	15	34.79	1.31
SO_4, mg/L	14	4	8	6.23	1.56
Cl, mg/L	9	1	8	1.58	2.23
Ca, mg/L	25.00	11.6	12	16.15	1.32
Mg, mg/L	2.10	0.97	12	1.45	1.30
Na, mg/L	2.30	0.34	8	0.68	1.96
K, mg/L	2.80	1.2	8	1.79	1.36
Cu, total, µg/L	79	1	15	20.45	2.95
Zn, total, µg/L	358	30	15	96.28	1.86
Cr, total, µg/L	14	2	15	4.57	2.08
Se, total, µg/L	1	1	7	1.00	1.00
Hg, total, µg/L	0.25	0.20	12	0.20	1.07
Ni, total, µg/L	100	50	7	55.20	1.30
Cd, total, µg/L	1.74	0.20	15	0.61	1.64
Pb, total, µg/L	612	57	15	141.68	1.77
Fe, total, µg/L	5,448	379	15	1,757.01	2.14
Mn, total, µg/L	388	25	15	96.53	2.01
Al, total, µg/L	4,944	361	10	1,250.72	2.32

Table V-6

Event Mean Concentrations
Summary Statistics
Central Business District (CBD)

Parameter	Max.	Min.	Number of observations	Geometric mean	Spread factor
pH, SU	7.6	6.1	15	-	-
Conductivity, µmhos/cm	230	79	14	-	-
TDS, mg/L	150	42	20	84.18	1.44
TSS, mg/L	360	29	20	93.92	1.91
NO_2+NO_3-N, mg/L	1.60	0.16	20	0.53	1.67
NH_3+NH_4-N, mg/L	0.27	0.010	20	0.11	2.23
TKN, mg/L	1.30	0.27	20	0.58	1.50
DKN, mg/L	0.80	0.16	16	0.36	1.57
TP, mg/L	0.35	0.070	20	0.19	1.54
DP, mg/L	0.11	0.010	16	0.04	1.88
SOC, mg/L	42.00	4.50	16	8.36	1.76
TOC, mg/L	47.00	7.50	20	12.96	1.49
COD, mg/L	140	21	20	62.48	1.61
Fecal coliform, No./100 ml	440,000	160	20	5,449.09	7.76
Fecal strep, No./100 ml	680,000	2000	16	40,780.20	4.40
BOD_5, mg/L	25.00	4.70	16	11.48	1.54
Total alkalinity, mg/L	57	25	20	37.30	1.31
SO_4, mg/L	31	8	12	14.39	1.57
Cl, mg/L	14	1	12	2.97	2.00
Ca, mg/L	63.0	11.4	16	25.59	1.56
Mg, mg/L	9.30	1.20	16	3.10	1.69
Na, mg/L	8.67	1.04	12	2.40	1.84
K, mg/L	4.60	1.80	12	2.68	1.31
Cu, total, µg/L	120	13	20	40.51	1.80
Zn, total, µg/L	520	122	20	274.23	1.51
Cr, total, µg/L	300	6	20	35.87	3.30
Se, total, µg/L	1	1	8	1.00	1.00
Hg, total, µg/L	0.4	0.2	17	0.23	1.29
Ni, total, µg/L	100	50	8	54.53	1.28
Cd, total, µg/L	3.4	0.5	20	1.04	1.58
Pb, total, µg/L	370	47	20	136.32	1.69
Fe, total, µg/L	9,300	1200	20	3,098.23	1.66
Mn, total, µg/L	482	40	20	115.16	1.77
Al, total, µg/L	6,600	770	14	1,840.88	1.83

Table V-7

Event Mean Concentrations
Summary Statistics
Strip Commercial (SC)

Parameter	Max.	Min.	Number of observations	Geometric mean	Spread factor
pH, SU	7.3	4.6	13	-	-
Conductivity, μmhos/cm	160	67	13	-	-
TDS, mg/L	113	29	18	62.75	1.49
TSS, mg/L	635	4	18	59.69	2.75
NO_2+NO_3-N, mg/L	1.50	0.020	18	0.33	2.50
NH_3+NH_4-N, mg/L	0.74	0.010	18	0.13	3.11
TKN, mg/L	2.92	0.28	18	0.68	1.89
DKN, mg/L	1.50	0.24	14	0.38	1.73
TP, mg/L	1.10	0.12	18	0.35	2.05
DP, mg/L	0.71	0.020	14	0.13	2.44
SOC, mg/L	18.0	4.5	14	7.06	1.59
TOC, mg/L	23.5	6.3	18	12.20	1.51
COD, mg/L	255	14	18	57.78	2.01
Fecal coliform, No./100 ml	187,000	165	18	6,965.51	6.70
Fecal strep, No./100 ml	2,000,000	11,000	14	48,309.60	3.80
BOD_5, mg/L	36.0	2.6	13	10.29	2.08
Total alkalinity, mg/L	56.0	1	18	27.68	2.37
SO_4, mg/L	20	4	10	7.68	1.67
Cl, mg/L	4	1	10	1.82	1.77
Ca, mg/L	27.0	12.9	14	18.87	1.31
Mg, mg/L	3.10	1.12	14	1.79	1.39
Na, mg/L	3.06	0.52	10	1.24	1.78
K, mg/L	2.4	1.1	10	1.53	1.29
Cu, total, μg/L	103	1	18	30.94	2.72
Zn, total, μg/L	621	67	18	149.61	1.64
Cr, total, μg/L	33	2	18	4.83	2.28
Se, total, μg/L	1	1	7	1.00	1.00
Hg, total, μg/L	0.42	0.20	15	0.24	1.34
Ni, total, μg/L	50	50	7	50.00	1.00
Cd, total, μg/L	3.80	0.50	18	0.92	1.60
Pb, total, μg/L	1,627	113	18	243.24	1.78
Fe, total, μg/L	11,900	869	18	2,184.69	1.87
Mn, total, μg/L	659	51	18	108.45	1.83
Al, total, μg/L	6,922	401	13	1,412.15	2.26

contribution of R2 to the data from the SC site needed to be subtracted. This was accomplished by: (1) multiplying the total flow at the SC and R2 sites for each storm by the respective EMC of each constituent to produce a load in milligrams, (2) the load at the R2 site was subtracted from the load at the SC site for common runoff events to produce the load contributed by the SC basin alone, and (3) the resulting calculated load from the SC basin was divided by the total flow at SC, minus the flow at R2, to produce the EMCs in the runoff from the SC basin alone.

The relative magnitude of the EMCs of copper, chromium, iron, zinc, cadmium, and lead are compared through their ranges and geometric means to EPA's Drinking Water Standards and aquatic toxicity levels[1] (see figure V-1). Figure V-1 illustrates that the runoff from each of the urban land use subbasins exceeds one of these reference numbers either in its maximum EMC or the geometric mean, or both. Notable in this regard are the figures for iron and lead where nearly all data exceed both the drinking water standard and the aquatic toxicity level. The figure for chromium indicates the opposite extreme with the majority of data falling below the aquatic toxicity level and the drinking water standard. In this data analysis context, the

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1. Aquatic toxicity levels are calculated with the water hardness an integral term in the equation. The water hardness used to calculate the toxicities in figure V-1 is the geometric mean of the water hardness EMCs.

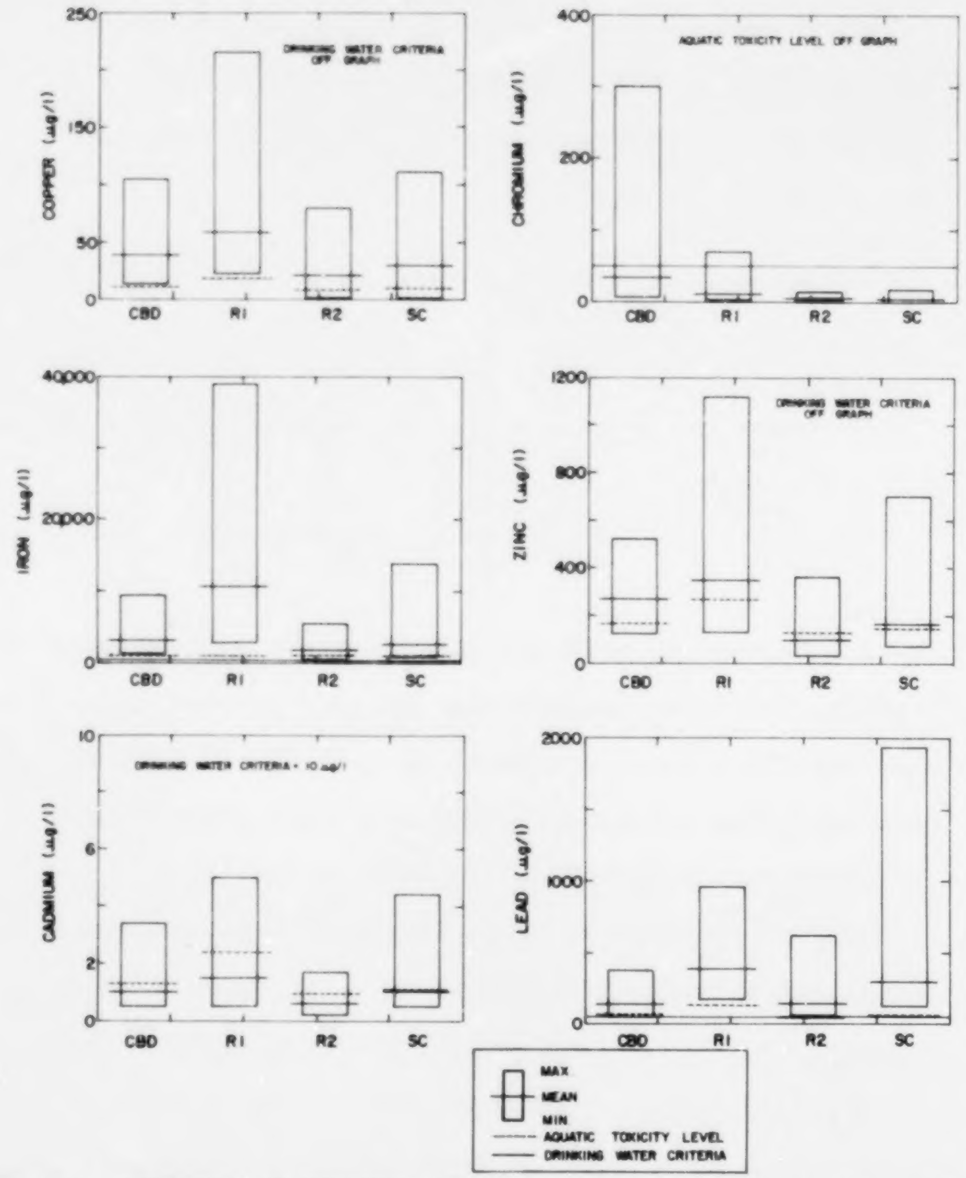

FIGURE V-1 COMPARISON OF GEOMETRIC MEANS AND RANGES OF EVENT MEAN CONCENTRATIONS IN URBAN RUNOFF.

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exceedance of these criteria seem to be of a much more serious nature than they really are when viewed in the context of a probability distribution for the above metals. For instance, the following values represent the probability (percent) that an individual sample from a runoff event will exceed the aquatic toxicity levels of 1000, 5000, 50, 10, 50, and 300 µg/L, respectively, for copper, zinc, chromium, cadmium, lead, and iron at each of the study sites.

Percent Probability of a Metal EMC Exceeding the Aquatic Toxicity Criteria

	CBD	R1	R2	SC
Copper	5.4	0.0	0.0	1.9
Zinc	1.9	0.0	0.0	0.0
Chromium	0.6	10.8	0.1	3.4
Cadmium	4.0	5.4	0.0	0.0
Lead	87.5	99.9	96.5	99.6
Iron	98.8	100	99.0	99.9

These probabilities, which were determined from the probability distributions of this study's metal EMC data, indicate that only the aquatic toxicity criteria for lead and iron would be exceeded during any significant number of storm runoff events. This analysis provides a broader perspective with which to evaluate the importance of metals contamination in urban runoff relative to the aquatic toxicity criteria. It should be noted, however, thtat certain environmental factors (e.g., water hardness, pH) can alter conditions such that the above probabilities may no longer be valid. A more extensive data base may be needed to accurately account for the environmental variation.

D. Stormwater Runoff Loads

Stormwater runoff loads for each of the constituents measured in the runoff samples from the four catchments (R1, R2, CBD, and SC) were determined by multiplying the EMC for each storm event by the total storm event runoff volume. Loadings for CBD and SC were calculated exclusive of their baseflows. In order to provide a means of comparing the different basins, the loadings are expressed in terms of mass (grams or milligrams) per hectare of drainage area, per centimeter of rainfall. The loading for each storm runoff event from each of the four catchments are shown in Appendix F. Table V-8 presents the mean load, and the minimum and maximum loads for all runoff events in the CBD, R1, R2, and SC subbasins. Loads at the CBD and SC sites were more variable than at the two residential sites (R1, R2) and nearly every constituent was higher in its mean load at the CBD and SC than at the R1 and R2 sites. This relation is illustrated graphically in figures V-2 and V-2a which show the minimum, maximum, and mean loads for total dissolved solids, total suspended solids, alkalinity, COD, sulfate, zinc, cadmium, copper, lead, ammonia, total organic carbon, and nitrite plus nitrate, at the CBD, SC, R1, and R2 sites. These figures are generally typical of the data presented in table V-8.

In terms of its mean load, each constituent in urban runoff can be categorized as either a low, moderate, or high load constituent. Table V-9 lists the constituents and their load magnitude category for all four of the catchments combined.

Table V-8

Mean, Minimum, and Maximum Loads in Urban Runoff - Knoxville, Tennessee
in grams per hectare per centimeter of rain (g/ha/cm)

	CBD				R1			
Constituent	N	$\bar{X}$	Min	Max	N	$\bar{X}$	Min	Max
Total dissolved solids	18	1,173	-	3,282	13	632	226	1,784
Total suspended solids	18	3,550	910	13,904	13	3,677	89	9,912
Nitrite plus nitrate	18	12	-	28	13	2.4	0.6	4.4
Ammonia	18	2.8	-	7.2	13	0.5	0.08	1.2
Total kjeldahl nitrogen	18	11	-	22	13	9.6	1.3	34
Dissolved kjeldahl nitrogen	-	-	-	-	11	1.9	1.1	2.9
Total phosphorus	18	4.4	-	9.7	13	4.8	1.1	11
Dissolved phosphorus	15	0.6	-	2.5	11	0.7	0.3	1.0
Soluble organic carbon	15	185	-	1,185	11	76	13	174
Total organic carbon	18	285	-	1,317	13	163	34	352
Chemical oxygen demand	18	1,855	394	3,891	13	784	75	2,380
Biochemical oxygen demand	15	326	-	716	11	88	21	302
Alkalinity	18	628	-	1,798	13	253	42	535
Sulfate	11	107	-	307	10	39	9	72
Chloride	11	1.3	-	14	10	10	2.1	23
Calcium	15	586	-	2,293	11	148	31	406
Magnesium	15	57	-	320	11	26	4.5	70
Sodium	11	0.2	-	2.3	10	4.1	1.0	9
Potassium	11	59	0.7	95	10	25	5	56

Table V-8

(Continued)

Mean, Minimum, and Maximum Loads in Urban Runoff - Knoxville, Tennessee
in grams per hectare per centimeter of rain (mg/ha/cm)

	CBD				RI			
Constituent	N	$\bar{X}$	Min	Max	N	$\bar{X}$	Min	Max
Total copper	18	1,173	444	2,683	13	451	78	1,444
Dissolved copper	-	-	-	-	2	38.4	7.5	69.4
Total zinc	18	7,748	1,969	20,206	13	2,583	450	5,947
Dissolved zinc	-	-	-	-	2	143	38	248
Total chromium	18	244	0	2,932	13	84	8.6	327
Dissolved chromium	-	-	-	-	2	12.5	9.9	15.0
Total selenium	7	17.9	0.2	37.5	7	4.4	2.1	7.5
Dissolved selenium	-	-	-	-	1	7.5	7.5	7.5
Total mercury	15	5.5	1.3	10.8	12	2.1	0.4	5.8
Dissolved mercury	-	-	-	-	1	1.5	1.5	1.5
Total nickel	7	595	0	1,636	7	236	103	375
Dissolved nickel	-	-	-	-	1	375	375	375
Total cadmium	18	29.2	9.7	135.3	13	11.2	2.3	29.7
Dissolved cadmium	-	-	-	-	2	2.2	1.5	2.9
Total lead	18	4,613	1,463	15,395	13	2,912	371	7,646
Dissolved lead	-	-	-	-	2	12.5	9.9	15.0
Total iron	18	116,198	45,709	394,479	13	83,597	5,813	386,589
Dissolved iron	-	-	-	-	2	1,029	218	1,840
Total manganese	18	4,172	1,264	20,266	13	4,284	544	11,641
Dissolved manganese	-	-	-	-	2	38.6	37.6	39.6
Total aluminum	-	-	-	-	9	98,835	8,536	406,414
Dissolved aluminum	-	-	-	-	1	495	495	495

Table V-8

(Continued)

Mean, Minimum, and Maximum Loads in Urban Runoff - Knoxville, Tennessee
in grams per hectare per centimeter of rain (g/ha/cm)

	R2				SC			
Constituent	N	$\bar{X}$	Min	Max	N	$\bar{X}$	Min	Max
Total dissolved solids	15	434	178	827	12	1,512	435	2,341
Total suspended solids	15	961	25	4,574	12	3,904	86	22,759
Nitrite plus nitrate	15	2.2	0.2	5.5	12	9	0	22
Ammonia	15	0.7	0.06	3.5	12	7	0.4	19
Total kjeldahl nitrogen	15	3.9	1.3	9	12	22	8.8	49
Dissolved kjeldahl nitrogen	12	1.9	0.7	5.5	9	13	5	41
Total phosphorus	15	2.0	0.7	5.7	12	11	3	31
Dissolved phosphorus	12	0.8	0.2	2.8	9	4	0	19
Soluble organic carbon	12	44	10	123	9	197	120	425
Total organic carbon	15	88	13	345	12	316	163	513
Chemical oxygen demand	15	425	99	1,889	12	2,254	385	8,794
Biochemical oxygen demand	11	51	18	154	-	-	-	-
Alkalinity	15	259	81	588	12	742	0	1,456
Sulfate	8	33	17	70	5	159	102	275
Chloride	8	8	4.4	19	5	27	0	39
Calcium	12	117	41	258	9	551	335	900
Magnesium	12	10	3.8	19	9	52	26	102
Sodium	8	3.6	1.9	7.2	5	0.7	0	2.4
Potassium	8	9	5.1	16	5	30	22	39

Table V-8

(Continued)

Mean, Minimum, and Maximum Loads in Urban Runoff - Knoxville, Tennessee
in grams per hectare per centimeter of rain (mg/ha/cm)

Constituent	R2				SC			
	N	$\bar{X}$	Min	Max	N	$\bar{X}$	Min	Max
Total copper	15	240	6	888	12	1,255	402	3,418
Dissolved copper	5	169	70	413	-	-	-	-
Total zinc	15	922	134	4,052	12	6,011	3,045	21,829
Dissolved zinc	5	265	58	619	-	-	-	-
Total chromium	15	41.2	7.4	140.8	12	175	8	522
Dissolved chromium	5	9.0	5.8	10.3	-	-	-	-
Total selenium	7	4.8	2.2	5.8	4	23.9	20.9	27.7
Dissolved selenium	1	5.8	5.8	5.8	-	-	-	-
Total mercury	12	1.3	0.4	2.8	9	6.9	4.2	12.9
Dissolved mercury	2	3.0	2.0	4.0	-	-	-	-
Total nickel	7	280	108	572	4	1,115	908	1,332
Dissolved nickel	1	290	290	290	-	-	-	-
Total cadmium	15	5.2	0.9	19.7	12	35.1	13.8	136
Dissolved cadmium	4	1.7	1.0	2.9	-	-	-	-
Total lead	15	1,384	192	6,921	12	11,853	3,563	60,301
Dissolved lead	5	84	12	201	-	-	-	-
Total iron	15	18,056	2,117	61,606	12	100,544	24,756	429,950
Dissolved iron	5	568	302	780	-	-	-	-
Total manganese	15	999	111	4,391	12	4,823	1,437	22,962
Dissolved manganese	5	202	29	722	-	-	-	-
Total aluminum	10	15,469	1,648	55,905	-	-	-	-
Dissolved aluminum	4	767	476	1,032	-	-	-	-

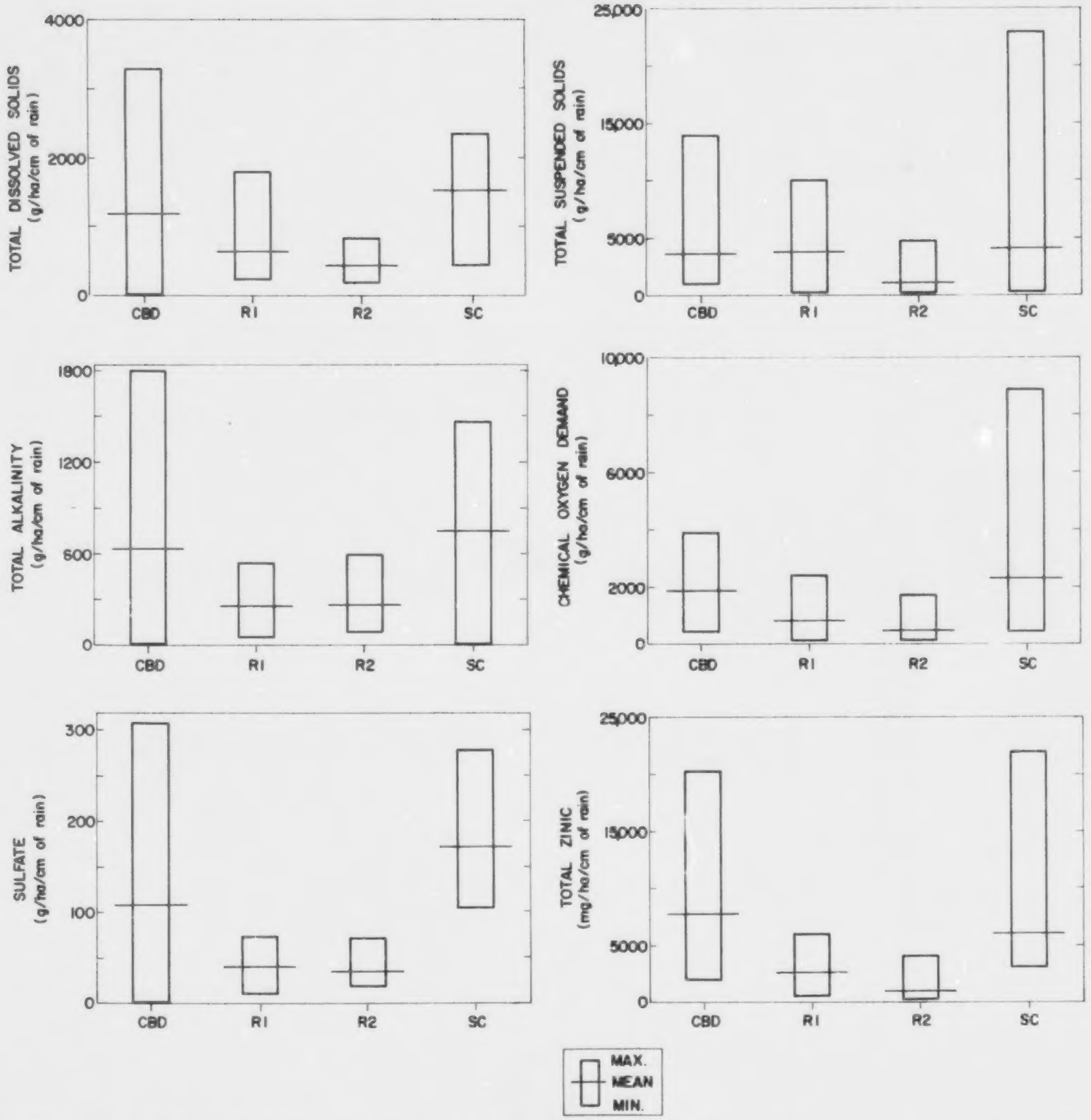

FIGURE V-2. MINIMUM, MAXIMUM AND MEAN LOAD OF VARIOUS CONSTITUENTS IN KNOXVILLE URBAN RUNOFF.

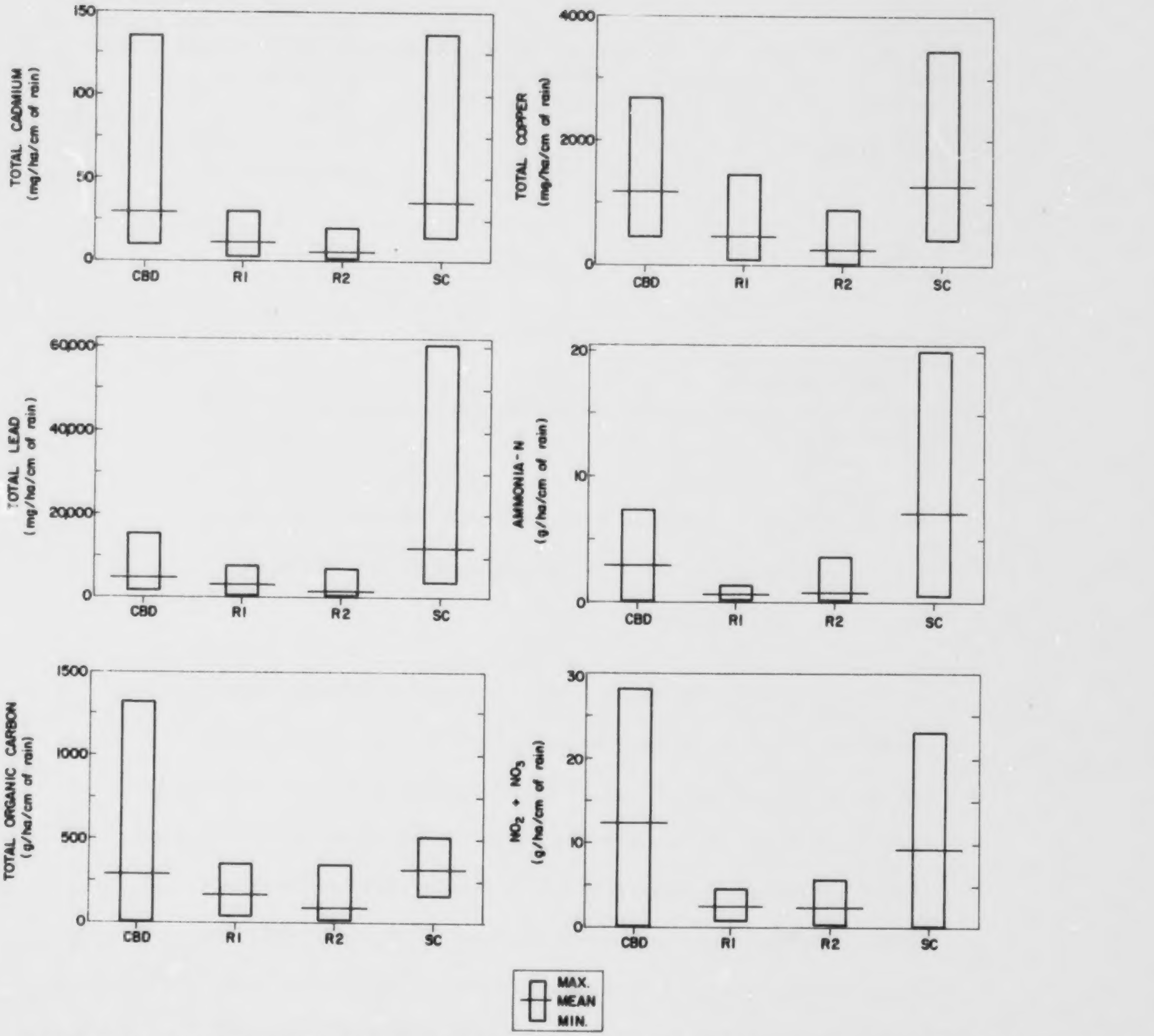

FIGURE V-2a. MINIMUM, MAXIMUM AND MEAN LOAD OF VARIOUS CONSTITUENTS IN KNOXVILLE URBAN RUNOFF.

Table V-9

Load Magnitude[*] of Constituents in Knoxville Urban Runoff

Low	Moderate	High
Magnesium	Alkalinity	Total suspended solids
Potassium	Calcium	Total dissolved solids
Nitrite plus nitrate	Biochemical oxygen demand	Chemical oxygen demand
Chloride	Total organic carbon	Aluminum
Phosphorus	Soluble organic carbon	Iron
Ammonia	Sulfate	Zinc
Kjeldahl nitrogen	Nickel	Lead
Sodium	Copper	Manganese
Cadmium		
Mercury		
Selenium		
Chromium		

[*] High = >1000 mass units
Moderate = 100 to 1000 mass units
Low = <100 mass units
Mass units are in micrograms for metals and milligrams for other constituents.

Although these categories were selected somewhat arbitrarily they do provide a qualitative assessment of the relative magnitude of urban runoff loads.

A quantitative assessment of receiving water impacts resulting from urban runoff loads were estimated through a comparison of wastewater treatment plant discharge loads to Fort Loudoun Reservoir with runoff loads from the Second Creek basin. Calculated estimates of annual loads of total suspended solids, BOD$_5$, ammonia, cadmium, chromium, copper, iron, nickel, and zinc were developed by multiplying the combined mean load (g/ha/cm rain) for the four study subbasins that occurred during the study period by the average annual rainfall for the basin, and the resulting product multiplied by the area of the Second Creek basin that drains to Fort Loudoun Reservoir. These annual loads are compared in table V-10 with the average annual loads from four wastewater treatment plants in the vicinity of Knoxville that discharge to Fort Loudoun Reservoir. This table shows that the annual load of suspended solids and five-day BOD to Fort Loudoun Reservoir from urban runoff exceeds the annual load from all four treatment plants combined. The annual load of copper, zinc, chromium, nickel, and iron to Fort Loudoun Reservoir were also higher in the urban runoff than in the wastewater treatment plants, while contributions of ammonia were generally greater for the treatment plants than from urban runoff.

E. Dissolved Versus Particulate Metals

As detailed in section III, composite samples from the CBD, SC, R2, and R1 sampling sites were analyzed for both total and dissolved metals. The percentage of the total concentration of each metal associated with suspended particulates was determined by subtracting the dissolved metal EMC from the total metal EMC and expressing the resulting value as a percentage of the total metal EMC. Table V-11 gives the percentage of the total metals EMC present in the particulate form in each of the composite samples collected from the individual storms, and the mean for all storms at each station and the mean for all stations combined. From the table it can readily be seen

Table V-10

Comparison of Annual Loads from Second Creek Urban Runoff with Wastewater Treatment Plant Discharges to Fort Loudoun Reservoir

Constituent	Second Creek Urban Runoff	Third Creek WWTP	Fourth Creek WWTP	Turkey Creek WWTP	Loves Creek WWTP
Total suspended solids, kg/yr	616,840	45,994	6224	1359[a]	1201
BOD_5, kg/yr	35,878	21,815	4935	4240	2158
Ammonia, kg/yr	540	2,724	3756	NA[b]	420
Copper, kg/yr	162	208	12	NA	NA
Zinc, kg/yr	923	62	9	NA	NA
Chromium, kg/yr	29	97	18	NA	NA
Nickel, kg/yr	101	102	21	NA	NA
Cadmium, kg/yr	4	20	4	NA	NA
Iron, kg/yr	16,600	435	66	NA	NA

a. permitted discharge
b. not available

Table V-11

Percentage of Total Metal EMC Present in the Particulate Phase

CENTRAL BUSINESS DISTRICT (CBD)

Storm No.	Cu	Zn	Cr	Cd	Pb	Fe	Mn	Al
3	31	96	21	90	97	100	94	-
13	67	81	0	50	94	99	86	97
15	-	50	33	60	94	94	-	94
17	90	75	83	54	94	99	89	93
19	63	74	67	64	100	99	76	96
20	74	88	62	91	99	100	97	99
23	25	75	82	71	97	100	71	86
$\bar{X}$	58	77	50	69	96	99	86	94

RESIDENTIAL SITE 1 (R1)

Storm No.	Cu	Zn	Cr	Cd	Pb	Fe	Mn	Al
9	99	99	85	93	100	99	100	-
16	89	94	98	96	98	99	91	100
17	68	94	78	60	98	99	96	98
19	94	96	97	90	100	100	100	100
$\bar{X}$	87	95	89	84	99	99	96	99

RESIDENTIAL SITE 2 (R2)

Storm No.	Cu	Zn	Cr	Cd	Pb	Fe	Mn	Al
9	0	80	91	0	98	94	96	-
17	75	83	75	86	96	97	91	96
19	70	87	75	75	98	99	97	98
21	50	70	93	80	84	98	91	92
23	-	50	50	-	94	98	53	92
$\bar{X}$	48	74	76	60	94	97	85	94

STRIP COMMERCIAL SITE (SC)

Storm No.	Cu	Zn	Cr	Cd	Pb	Fe	Mn	Al
3	70	95	97	75	96	99	93	-
9	0	93	5	-	96	93	92	-
15	62	70	67	60	96	97	78	94
17	-	85	80	88	98	99	92	94
19	72	93	86	82	99	99	91	97
21	17	81	50	88	97	99	73	-
23	56	72	67	88	98	100	56	94
$\bar{X}$	46	84	84	80	97	98	82	94
Mean of all storms at all sites	58	81	67	73	96	98	86	95

Table V-12

Correlation Between Particulate Phase Metals and Total Suspended Solids (TSS)

		Correlation Coefficients							
		Cu	Zn	Cr	Cd	Pb	Fe	Mn	Al
CBD	TSS	0.31	0.85	0.57	0.82	0.89	0.87	0.85	0.79
SC	TSS	0.34	0.48	0.13	0.40	0.56	0.64	0.64	0.90
R1	TSS	0.67	0.67	0.58	0.58	0.65	0.86	0.53	0.81
R2	TSS	-0.23	0.25	-0.07	0.43	0.38	0.13	0.46	0.96

that copper has the lowest overall percentage distribution in the particulate phase (59 percent), and conversely, is the most soluble metal (41 percent). Chromium and cadmium are respectively the second and third most soluble metals at 33 and 26 percent, followed by zinc (18 percent soluble), and manganese (13 percent soluble). Aluminum, lead, and iron are respectively the least soluble metals (<10 percent soluble).

The association between particulate metals and total suspended solids (TSS) is confirmed through the correlation coefficients shown in table V-12 above. Copper, which has the lowest percentage in the particulate phase, is generally the least correlated with TSS. Conversely, lead, iron, and aluminum, which have a high percentage of their total concentration in the particulate phase are generally highly correlated with TSS.

F. Bacteriological Identification

During the laboratory analysis of runoff samples for fecal coliform and fecal streptococcus bacteria, a prolific noncoliform bacterial growth of pink colonies appeared on the fecal coliform media. Subsequently, special runoff samples were collected in June 1982 from the CBD, R1, R2, and SC sampling locations for identification of the noncoliform bacteria. Using selective culture techniques, it was determined that there was a 99.9 percent probability that the noncoliform organisms were Salmonella enteritides at the CBD and SC sites, 98.7 percent probability of Salmonella enteritides at the R2 site, and 92.7 percent probability of Salmonella enteritides at the R1 site. This was not surprising, however, since previous investigators have found that when fecal coliforms exceed 200 organisms per 100 ml, the probability of the presence of Salmonella generally approaches 100 percent and considering that the geometric means of the fecal coliform data from the composite samples were 6680, 4939, 3925, and 11,304 organisms per 100 ml, respectively, at the CBD, SC, R2, and R1 sites, and that individual storm values as high as 10,000 organisms per 100 ml were not uncommon. Indeed, EPA's fecal coliform bacteria criterion for bathing waters is a geometric mean of 200 fecal coliforms per 100 ml, based on a minimum of five samples over a 30-day period, and 400 per 100 ml in 10 percent of samples taken during a 30-day period. In all instances where appropriate sampling requirements were met in this study, the fecal coliform concentration exceeded this EPA criterion.

Ratios of fecal coliform bacteria to fecal streptococcus bacteria were calculated to determine potential sources of bacterial contamination. Ratios of 4.0 or higher generally indicate the presence of domestic wastes, while ratios below 0.6 typically indicate contamination from animal wastes, or stormwater runoff. Table V-13 presents the ratios of fecal coliform to fecal streptococcus densities measured at each runoff sampling site. The data indicates, as one might expect, that nearly all ratios are less than 0.6, indicative of stormwater runoff. In fact, respectively, for the CBD, SC, R2, and R1 sites, the percentage of ratios less than or equal to 0.6 were 80, 77, 73, and 82. This would tend to indicate that the stormwater runoff at these sites is heavily contaminated by bacteria originating from the feces of domestic animals such as dogs and cats. However, the magnitude of contamination by both fecal and fecal strep bacteria is considerable.

The distribution of fecal coliform loading (in terms of numbers of organisms) within the total runoff for a rainfall event was determined for a number of selected storms in which clearly defined coliform pollutographs could be developed. The percentage of the total coliform load was determined for the corresponding percentage of the total storm runoff in order to determine what proportion of the runoff contained the most significant quantity of the fecal coliform loading. This relationship is illustrated in figure V-3, which shows linear least squares regressions of the percent fecal coliform load versus percent runoff for selected storms from the CBD, SC, and R2 subbasins. As the slopes in the regression equations

Table V-13

Ratios of Fecal Coliform to Fecal Streptococcus Bacteria in Urban Runoff

Storm	CBD	SC	R2	R1
1	0.8	NS	0.9	1.1
2	0.8	0.3	0.7	10.0
3	0.3	1.0	NS	NS
4	NS	2.0	25.3	NS
5	1.0	NS	NS	NS
6	0.1	0.1	NS	NS
7	0.4	0.2	0.6	0.1
8	0.6	NS	0.02	0.6
9	NS	0.2	0.1	0.2
11	NS	NS	NS	0.3
12	0.5	0.02	0.08	0.1
13	0.1	NS	NS	NS
14	0.1	0.02	NS	0.1
15	0.02	0.04	NS	NS
16	NS	NS	NS	0.01
17	0.03	0.1	0.01	0.01
18	0.01	NS	NS	NS
19	NS	0.01	0.01	0.1
20	0.01	NS	NS	NS
21	NS	0.001	0.01	NS
22	NS	NS	NS	NS
23	0.2	1.6	0.01	NS
Percent $\leq$ 0.6	80%	77%	73%	82%

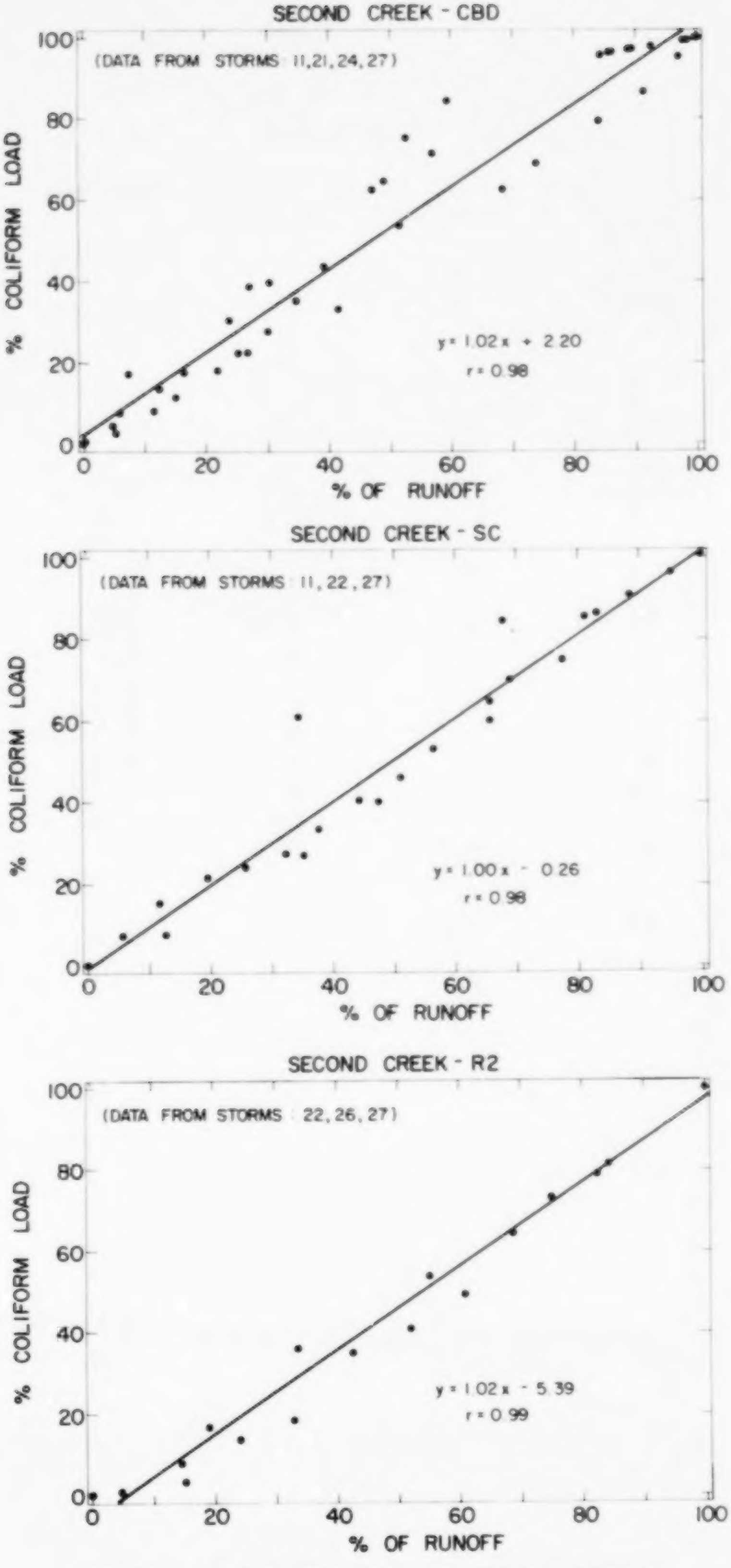

FIGURE V-3 PERCENT FECAL COLIFORM LOADING VERSUS PERCENT OF STORM RUNOFF.

indicate by their closeness to unity, incremental increases in the percentage of runoff flow contains a proportionate incremental increase in the percentage of fecal coliform load. Thus, the coliform mass is equally distributed throughout these runoff events with no specific portion of the hydrograph accounting for a disportionate quantity of the coliform load.

G. Priority Pollutants

As previously described in section II, composite samples were collected from the CBD, SC, R2, and R1 sampling sites for the analysis of the 129 priority pollutants (excluding asbestos and dioxin). The results of those analysis are presented in Appendix G. As these data tables indicate, analysis was performed on samples collected on two occasions--October 2, 1981 and January 3, 1982. The results of the analysis for organic constituents show that with only one minor exception (fluoranthane), no detectable concentrations of organic priority pollutants were found.

Priority pollutant metals, however, were detected, notably copper, lead, and zinc. These are the same metals that are present at significant levels in the more extensive runoff data base previously discussed.

VI. Wet and Dry Precipitation - Quality Data

Detailed descriptions of the collection procedures for the precipitation samples were given in Section III, and the concentrations of the constituents analyzed are presented in Appendix H. Using the concentration data in Appendix H, wet and dryfall loads were calculated for each storm (wetfall) and antecedent dry period (dryfall), in each of the four study catchments. These loads are presented in table VI-1.

In table VI-2, the mean loads of the water quality constituents measured in the wetfall and dryfall samples for the study period are presented for the CBD, R1, R2, and SC subbasins, and all subbasins combined. Interbasin comparison cannot be made from the data in this table because of unequal collection periods. The tables purpose is to illustrate the magnitude of difference between the dryfall and wetfall loading within a basin and for all the data combined. The table shows, with the exception of chloride at all sites, and aluminum at the R2 and SC sites, the atmospheric inputs of water quality constituents in the wetfall greatly exceeds those from dryfall. Further discussion of the differential between the input and output loads at the four water quality study sites is presented in section VIII.

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Table VI-1

Knoxville Urban Runoff Study
Wetfall Loading Rates[a]

(Values in mg per hectare per day)

	CBD												
Storm	TDS	TSS	TKN	TP	NO_3	TOC	COD	K	Ca	Mg	Na	Cl	SO_4
1	-	-	-	-	-	-	-	-	-	-	-	-	-
2	2,928.6	225.27	74.341	9.0110	326.648	1058.79	1,802.2	33.791	245.549	38.071	94.615	90.110	810.99
3	-	-	-	-	-	-	-	-	-	-	-	-	-
5	2,957.2	591.45	768.879	17.7434	443.584	6210.18	37,261.1	147.861	887.169	150.819	875.339	295.723	4140.12
6	401.5	80.30	126.868	0.8030	100.370	931.43	5,058.6	40.148	194.316	34.126	331.622	64.237	1035.82
7	1,980.5	198.05	31.689	1.9805	39.611	1326.96	3,565.0	7.922	65.358	11.883	9.903	19.805	415.91
8	8,020.2	631.09	105.182	2.6296	94.664	1209.60	2,892.5	15.777	118.330	21.036	26.296	52.591	1393.67
9	-	-	-	-	-	-	-	-	-	-	-	-	-
10	1,670.4	835.21	117.973	3.1320	70.993	1472.06	4,593.7	39.672	428.045	68.905	80.389	70.993	668.17
11	1,556.9	0.00	77.845	1.9461	48.653	739.53	1,167.7	11.677	54.492	13.818	46.707	58.384	389.23
12	1,472.1	176.65	35.330	2.9442	23.554	500.51	2,060.9	32.386	35.330	7.655	35.330	58.884	294.42
13	2,554.8	140.37	112.299	2.8075	56.150	1122.99	3,088.2	33.690	154.411	24.144	72.994	106.684	814.17
14	1,179.9	52.44	45.886	1.3110	68.174	642.41	1,048.8	9.177	39.331	5.900	24.910	20.977	393.31
15	1,894.5	1150.21	9.021	1.1277	11.277	225.53	112.8	4.511	37.213	4.736	-	25.936	214.26
17	738.5	644.20	40.851	1.5712	31.424	345.67	628.5	-	70.704	10.998	-	-	-
18	1,061.2	69.81	15.359	1.3963	9.774	153.59	139.6	-	195.477	5.585	-	-	-
19	1,432.5	0.00	55.981	1.6465	29.637	411.62	1,152.5	-	34.676	8.232	-	-	-
20	6,865.4	1705.96	68.654	2.0804	72.815	1165.04	3,120.7	-	224.687	37.448	-	-	-
21	1,295.2	179.89	43.174	5.3967	17.989	359.78	539.7	-	14.391	7.196	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-	-	-
24	10,076.6	1332.71	71.511	19.5030	243.788	1235.19	-	-	344.553	61.760	-	-	-
25	2,155.5	1474.85	26.093	2.2690	57.859	533.21	1,701.7	-	256.397	38.573	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-	-	-

a. Based on quality control report (some numbers were changed because of container leaching).

Table VI-1

(Continued)

Knoxville Urban Runoff Study
Wetfall Loading Rates[a]

(Values in mg per hectare per day)

	R1											
Storm	TDS	TSS	TKN	TP	NO_3	TOC	COD	K	Ca	Mg	Na	Cl	SO_4
1	-	250.384	48.8249	0.62	10.0154	613.441	2879.42	2.5038	18.78	2.5038	3.1298	6.2596	125.192
2	193.72	19.372	5.6178	1.16	21.3089	127.539	445.55	3.2932	22.66	3.5450	14.9162	17.4346	77.487
7	-	155.815	2.1814	0.31	6.2326	467.445	1869.78	3.4279	12.78	2.4307	2.8047	0.3116	56.093
8	370.20	0.000	17.5998	0.30	10.3171	166.895	273.10	2.7310	18.51	3.2469	3.6413	6.0689	151.723
9	241.38	4.554	7.2869	0.45	3.1880	273.259	865.32	3.1880	18.67	3.0514	2.2772	4.5543	36.435
10	-	-	-	-	-	-	-	-	-	-	-	-	-
11	137.05	0.000	4.4542	0.17	1.0279	85.658	102.79	1.3705	6.34	0.9080	5.3108	6.8527	6.853
12	847.02	0.000	13.5523	0.67	5.4209	128.747	677.61	16.2627	25.75	2.3039	33.8807	13.5523	74.537
13	1274.66	254.041	26.7411	0.44	12.9249	200.558	891.37	17.8274	2852.38	22.6854	-	24.0670	164.903
14	164.44	191.143	5.4813	0.14	7.3084	141.952	393.53	1.6866	4.92	0.6606	2.5298	2.5298	46.380
15	276.73	15.134	1.7296	0.21	1.9458	38.916	43.24	0.8648	8.22	1.0161	3.6754	4.9726	36.754
16	-	-	-	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-	-	-
19	509.24	101.850	26.3612	1.19	10.7841	149.779	479.25	-	10.78	1.7974	-	-	-
21	255.73	31.966	10.9598	2.28	3.6533	502.324	182.66	-	9.59	2.2833	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-	-	-
27	764.07	132.882	5.9797	1.32	7.9729	69.763	265.76	-	7.64	1.6610	-	-	-

a. Based on quality control report (some numbers were changed because of container leaching).

Table VI-1

(Continued)

Knoxville Urban Runoff Study
Wetfall Loading Rates[a]

(Values in mg per hectare per day)

	R2												
Storm	TDS	TSS	TKN	TP	NO_3	TOC	COD	K	Ca	Mg	Na	Cl	SO_4
1	-	4670.37	198.74	0.79	12.918	268.30	695.59	6.9559	22.855	2.9811	4.9685	7.9496	168.928
2	189.1	18.91	41.60	0.37	17.018	213.67	718.53	1.7018	9.643	1.4181	26.4720	9.4543	47.271
4	1,369.8	342.45	453.75	0.85	214.033	659.22	5051.18	13,6981	84.757	8.9038	17.1226	34.4253	787.641
7	688.3	34.42	55.07	0.34	6.883	96.37	172.09	2.0650	11.358	1.7553	8.2601	3.4417	48.184
8	690.1	89.58	136.03	0.66	11.280	162.57	530.83	2.6542	15.261	3.2182	3.3177	6.6354	165.885
9	0.0	175.40	68.79	0.34	6.535	113.50	240.75	4.1271	46.086	6.4658	4.4710	6.8785	61.907
10	196.8	39.36	87.57	0.19	5.117	111.19	265.67	1.7711	13.972	1.5743	4.3294	1.9679	55.101
11	355.4	0.00	44.43	0.22	7.553	57.76	266.58	1.3329	2.222	1.0886	6.8868	11.1077	55.538
12	249.5	0.00	226.82	8.69	6.049	105.85	415.84	3.4023	4.158	1.0585	4.9144	3.7803	41.584
14	327.8	7.34	61.15	0.24	12.474	80.71	146.75	1.4675	4.403	0.7582	4.6472	2.4459	73.377
15	-	-	-	-	-	-	-	-	-	-	-	-	-
17	794.1	4.93	167.70	0.98	11.345	236.76	394.59	-	12.331	2.4662	-	-	-
18	173.3	35.14	23.42	0.23	1.874	128.83	257.66	-	6.559	1.1712	-	-	-
19	453.4	48.58	107.95	0.53	8.096	172.72	377.84	-	10.795	1.6193	-	-	-
21	808.9	63.86	141.91	1.41	9.224	709.53	1490.02	-	7.095	2.8381	-	-	-
22	24,457.2	2870.56	1578.81	5.74	74.635	1779.75	4104.90	-	137.787	28.7056	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-	-	-
26	14,772.7	1926.88	620.88	4.28	55.665	1177.54	6637.03	-	55.665	14.9868	-	-	-
27	441.2	41.12	57.57	0.41	9.869	102.80	287.84	-	6.168	1.6448	-	-	-

a. Based on quality control report (some numbers were changed because of container leaching).

Table VI-1

(Continued)

Knoxville Urban Runoff Study
Wetfall Loading Rates[a]

(Values in mg per hectare per day)

	SC												
Storm	TDS	TSS	TKN	TP	NO_3	TOC	COD	K	Ca	Mg	Na	Cl	SO_4
1	-	-	-	-	-	-	-	-	-	-	-	-	-
2	858.1	85.81	34.325	4.29	60.069	283.18	1,115.6	7.7232	62.644	10.8983	30.035	42.9065	283.18
3	372.3	62.04	9.617	0.93	18.613	232.66	558.4	2.7919	17.062	2.9470	8.996	9.3064	89.96
4	1,148.5	229.69	76.949	1.14	321.570	2641.47	10,106.5	13,7816	83.838	10.4510	42.493	45.9386	1148.47
6	286.0	28.60	44.900	1.14	24.881	1244.04	6,217.3	7.4356	68.351	11.8112	131.840	11.4395	297.43
7	1,311.4	81.96	13.114	0.81	16.392	360.63	737.7	8.1962	31.965	54.9143	16.392	8.1962	131.14
8	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-
10	526.4	230.28	30.923	0.65	13.488	355.29	1,006.6	5.2635	42.437	8.5532	60.530	13.1588	82.24
11	713.9	47.59	14.277	0.79	25.381	237.95	396.6	8.7249	15.070	4.0452	38.865	31.7268	198.29
12	780.5	0.00	9.647	0.87	14.032	157.86	613.9	3.5081	9.647	2.1048	4.385	8.7702	96.47
14	669.9	0.00	21.773	0.55	32.380	251.22	614.1	6.1411	46.337	2.4564	12.840	12.8404	167.48
15	1,639.3	145.87	0.695	0.69	6.946	111.14	69.5	4.8624	14.587	2.1534	10.144	13.1980	97.25
17	1,374.8	167.66	16.766	1.67	21.795	285.02	335.3	-	62.871	9.2211	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-	-	-
19	458.5	116.87	19.778	0.89	13.485	503.45	1,258.6	-	30.567	4.4951	-	-	-
21	1,142.5	91.40	25.134	2.28	91.398	239.92	342.7	-	5.712	4.5699	-	-	-
22	16,911.9	2458.30	198.441	5.92	74.045	1865.94	4324.2	-	228.059	38.5035	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-	-	-	-	-	-
26	2,607.6	372.51	34.767	1.24	32.284	620.85	3973.4	-	39.734	9.9336	-	-	-
27	5,914.2	525.71	52.571	2.62	31.543	499.42	1971.4	-	61.771	13.1427	-	-	-

[a] Based on quality control report (some numbers were changed because of container leaching).

Table VI-1

(Continued)

Knoxville Urban Runoff Study
Dryfall Loading Rates[a]

(Values in kg per hectare per day)

	CBD										
Storm	TKN	TP	NO_2+NO_3	TOC	COD	K	Ca	Mg	Na	SO_4	Cl
1	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	2688.00	9600.0	76.800	1785.60	230.400	576.000	-	-
3	-	-	-	-	-	-	-	-	-	-	-
5	27.400	13.7000	54.8000	2055.00	9590.0	41.100	1027.50	10.960	191.800	342.500	68.500
6	123.300	6.8500	54.8000	1781.00	2740.0	27.400	411.00	54.800	95.900	479.500	68.500
7	13.200	0.8250	6.6000	165.00	495.0	3.300	108.90	13.200	4.950	33.000	8.250
8	7.272	2.0808	7.2720	228.96	1036.8	8.280	202.32	23.040	6.257	93.600	10.368
9	85.200	7.1000	28.4000	2272.00	2840.0	56.800	511.20	93.720	42.600	284.000	142.000
10	3.475	0.4345	3.0400	173.50	565.0	3.910	119.50	17.800	2.170	39.100	2.170
11	8.019	11.6640	2.9160	102.06	291.6	1.458	34.29	5.832	6.561	21.870	3.645
12	112.005	0.6994	6.9939	839.61	5591.7	55.917	294.12	47.538	41.895	69.939	69.939
13	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-	-	-	-

a. Based on quality control report (some numbers were changed because of container leaching).

Table VI-1

(Continued)

Knoxville Urban Runoff Study
Dryfall Loading Rates[a]

(Values in kg per hectare per day)

Storm	R1										
	TKN	TP	NO_2+NO_3	TOC	COD	K	Ca	Mg	Na	SO_4	Cl
1	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-
7	13.300	0.8330	6.670	267.00	667.0	6.670	53.30	8.330	23.300	33.30	8.330
8	2.772	0.4614	1.848	101.40	277.2	2.772	57.24	6.900	1.848	16.14	2.310
9	75.000	6.2500	25.000	3750.00	23,750.0	50.000	325.00	59.000	62.500	187.50	62.500
10	2.104	0.4200	2.948	92.80	252.8	3.788	66.80	6.920	2.104	21.04	1.052
11	1.938	0.4836	1.938	0.19	290.4	4.836	32.88	4.548	8.700	19.38	4.836
12	71.740	4.4880	8.942	1519.80	5,372.0	35.700	107.44	17.000	35.700	178.84	89.420
13	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-

a. Based on quality control report (some numbers were changed because of container leaching).

Table VI-1

(Continued)

Knoxville Urban Runoff Study
Dryfall Loading Rates[a]

(Values in kg per hectare per day)

	R2										
Storm	TKN	TP	NO_2+NO_3	TOC	COD	K	Ca	Mg	Na	SO_4	Cl
1	432.00	57.600	28.800	960.00	3,600.0	456.00	129.600	28.800	9.60	96.000	48.000
2	1696.00	339.200	212.000	7844.00	55,120.0	2544.00	763.200	190.800	1335.60	530.000	318.000
4	133.20	11.100	222.000	3108.00	11,100.0	66.60	777.000	88.800	710.40	333.000	333.000
7	1.60	0.200	0.800	48.00	79.9	1.60	5.592	0.800	1.60	6.000	0.199
8	23.36	10.200	2.550	110.16	212.2	11.88	135.600	5.406	4.67	14.841	4.248
9	218.40	13.650	54.600	6552.00	16,380.0	218.40	382.200	81.900	218.40	409.500	409.500
10	25.82	3.875	3.013	301.28	772.8	0.86	18.480	5.230	3.23	25.816	3.226
11	1.26	0.630	17.640	151.20	630.0	2.52	0.001	0.003	18.90	151.200	25.200
12	257.81	102.966	10.297	1029.66	4,134.4	20.67	72.391	11.318	113.18	51.640	51.640
14	-	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-

[a] Based on quality control report (some numbers were changed because of container leaching).

Table VI-1

(Continued)

Knoxville Urban Runoff Study
Dryfall Loading Rates[a]

(Values in kg per hectare per day)

	SC										
Storm	TKN	TP	NO_2+NO_3	TOC	COD	K	Ca	Mg	Na	SO_4	Cl
1	60.000	10.0000	20.000	1200.00	4,250.0	190.000	365.00	85.00	10.000	100.000	25.000
2	7.000	1.0000	5.000	100.00	700.0	3.000	76.00	8.00	27.000	15.000	10.000
3	39.000	3.0000	6.000	540.00	1,800.0	9.000	66.00	9.00	90.000	30.000	45.000
4	2.000	0.5000	25.000	90.00	600.0	4.000	73.00	77.00	28.000	25.000	15.000
6	40.000	1.0000	8.000	240.00	800.0	4.000	44.00	8.00	18.000	70.000	10.000
7	43.940	13.0000	6.500	357.50	650.0	6.500	74.75	19.50	14.690	24.440	8.125
8	189.000	13.5000	81.000	8100.00	91,800.0	189.000	1323.00	2079.00	81.000	945.000	135.000
9	2.838	0.2028	2.838	243.30	771.0	2.433	54.00	11.19	3.240	14.190	2.028
10	3.000	0.4614	3.924	69.00	184.8	4.152	94.80	20.28	3.462	32.280	3.462
11	5.720	0.4760	0.952	209.60	380.8	8.560	80.00	7.60	8.560	19.040	4.760
12	52.326	5.2326	10.449	626.94	3,142.8	62.694	302.94	56.38	52.326	52.326	52.326
14	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-

a. Based on quality control report (some numbers were changed because of container leaching).

Table VI-2

Mean Loads of Water Quality Constituents in Wetfall and Dryfall Samples

(values in grams)

	CBD		R1		R2		SC		All Basins Combined	
Constituent	Wetfall	Dryfall	Wetfall	Dryfall	Wetfall	Dryfall	Wetfall	Dryfall	Wetfall	Dryfall
TDS	22,143	-	60,589	-	113,824	-	117,876	-	77,949	-
TSS	5,000	-	14,896	-	35,262	-	13,070	-	16,851	-
pH (SU)	4.25	-	4.18	-	4.10	-	4.19	-	4.18	-
TKN	572	0.44	2,042	0.92	1,899	18.2	2,076	2.0	1,590	5.4
TP	25.6	0.08	105	0.13	156	3.4	108	0.30	96.3	1.0
NO_2+NO_3	532	-	1,275	-	2,269	-	3,156	-	1,773	-
TOC	6,916	6.9	41,862	13.0	33,210	98.8	40,039	17.3	29,131	34.3
COD	19,028	30.5	127,641	57.0	96,210	705	129,186	57.7	89,724	218
K	161	0.31	613	0.54	588	47.1	653	0.80	491	10.9
Ca	1,250	4.8	9,649	8.0	2,648	14.7	3,295	12.2	3,887	10.0
Mn	174	0.67	446	1.2	451	2.9	1,095	2.8	526	1.9
Na	560	0.49	1,244	0.55	1,669	29.1	3,453	1.9	1,703	7.2
Cl	426	531	1,231	466	1,490	8,714	1,648	1,153	1,164	2,506
SO_4	5,425	4,833	12,976	3,932	20,451	16,777	19,516	5,300	14,128	7,392
Fe	207	0.76	749	1.5	699	2.8	955	1.9	630	1.7
Mn	14.0	0.06	41.4	0.08	44.4	0.21	45.9	0.22	35.3	0.15
Cu	84.0	0.03	272	0.11	373	0.74	523	0.13	304	0.25
Zn	106	0.11	171	0.12	190	0.30	186	0.20	161	0.19
Cr	5.5	0.003	32.2	0.008	14.0	0.07	16.6	0.01	16.0	0.024
Se	2.2	0.04	6.3	0.004	7.2	0.04	5.4	0.007	5.2	0.023
Hg	2.3	0.0005	3.0	0.004	2.2	0.11	7.3	0.005	3.6	0.029
Ni	87.8	0.21	406	0.24	420	2.3	272	0.36	293	0.78
Cd	1.3	0.002	8.4	0.001	4.0	0.01	4.8	0.002	4.4	0.004
Pb	27.9	0.08	73.8	0.28	89.8	3.8	86.9	0.20	67.9	1.1
Al	232	73.6	483	458	475	675	639	729	445	475

VII. Hydrology in Carbonate Rock Areas of Knoxville

A. Background

In an earlier study of the effects of urbanization on streamflow quantity and quality in Knoxville, Betson (1976) showed that the hydrology of urban areas could be significantly affected if the area was underlain by soluble carbonate rocks. Table VII-1 adapted from that report shows the annual average yield of runoff for each of the four watersheds studied. Plantation Hills and First Creek watersheds lie to the east of Second Creek while Third and Fourth Creek watersheds lie to the west. Third Creek watershed had very little soluble carbonate rock present and the runoff yield was considered indicative of what could generally be expected in the absence of carbonate rock. At Plantation Hills where the percentage of impervious area was only slightly less than in the Third Creek watershed, the yield of runoff was about one-tenth that of Third Creek watershed. This difference was attributed to the presence of very soluble carbonate rock underlying the Plantation Hills watershed. The yield of runoff at Fourth Creek, also completely underlain by very soluble carbonate rock, was higher than that at Plantation Hills; however, the impervious area is more extensive in the Fourth Creek watershed than in the Plantation Hills area. At First Creek, the slightly higher yields of runoff (than at Plantation Hills) were attributed to shale which underlies the upper portions of the watershed.

Table VII-1

Comparison of Four Knoxville Study Watersheds

(after Betson, 1976)

	Watershed			
	Plantation Hills	First Creek	Third Creek	Fourth Creek
Drainage area, mi^2	0.24	0.50	1.60	0.82
Percent impervious	23	16	18	45
Percent underlain by soluble carbonate rock[a]	100	50	0	100
Mean rainfall, WY72-74, in.	60.2	61.4	59.2	60.9
Mean runoff, WY72-74, in.	3.9	6.4	33.2	13.8[b]
Yield (runoff/rainfall)	0.06	0.10	0.56	0.26[c]

a. Based on estimated value for parameter PKARST
b. Missing record November 1, 1973 through January 31, 1974
c. Adjusted for missing records

In addition to affecting the yield of runoff in selected watersheds, soluble carbonate rock had other effects upon the local watershed hydrology as follows: (1) stream baseflow is markedly reduced, or eliminated, in carbonate areas; (2) storm peak discharges are reduced; (3) there is an increase in the impact of urbanization on flooding; and (4) the transport of water quality contaminants from a watershed is reduced. These effects on streamflow caused by drainage into the carbonate rock systems are not well understood nor generally recognized.

The Knoxville study by Betson (1976) was planned to obtain data needed to modify an existing watershed model developed to quantify the effects of land-use changes upon hydrology so that it could handle the effects of urbanization. Empirical algorithms were developed and tested by using the model to simulate flows at the four study watersheds. The model which incorporates these algorithms is called TVA-HYSIM and was subsequently modified to be used interactively. The TVA-HYSIM model is used in the Second Creek study to demonstrate how carbonate terrain modifies the effects of urbanization on streamflow yields and storm runoff; the nature of the hydrologic changes caused by rapid drainage into solution channels; and how other models might be modified to handle the effects on streamflow caused by soluble carbonate rock.

B. Relevant Algorithms Used in TVA-HYSIM

TVA-HYSIM links a continuous daily streamflow module with a storm hydrograph module. The model is well documented (Betson, et al, 1980; Betson et al, 1981b); therefore, it will not be presented here. TVA-HYSIM is a regionalized model and there are internal provisions in the model for predicting most of the parameters from easily measured watershed characteristics which are the model input.

There are four algorithms in the model which are relevant to this study that determine the amount of storm runoff generated from impervious surfaces and/or changes in streamflow caused by drainage into soluble carbonate rock. The four algorithms accomplish the following: (1) control the storm runoff generated from impervious surfaces; (2) determine losses (into pervious surfaces) of runoff originating from impervious areas; (3) control the loss of potential storm runoff from pervious surfaces; and (4) determine the loss of potential baseflow in a surface stream. In this context, the model generates potential runoff from impervious and pervious areas based upon basin characteristics, antecedent conditions, and rainfall. This potential runoff is then modified to reflect the effects of drainage into the carbonate-rock cavity system. Consequently, both the potential runoff and the simulated streamflow are available from the model.

The algorithm used in TVA-HYSIM to generate runoff from impervious surfaces was presented by Miller and Viessman (1972) based upon analyses of data collected in Maryland and Illinois. This algorithm is of the form:

$$IRO = 1.165\ (FIMP-0.17)\ RFa \qquad \text{Eq. 1}$$

where:

IRO = storm runoff from impervious areas, in inches

FIMP = fraction of the watershed which is impervious

RFa = storm rainfall less the initial abstraction, in inches

If the impervious surfaces in a watershed total less than 17 percent (in which case all runoff originating from impervious surfaces should infiltrate into pervious surfaces), there is a provision in TVA-HYSIM to generate impervious area runoff from areas directly connected to the stream, i.e., road drains or storm sewers. The extent of these directly connected areas is not easily determined. More recently, Alley and Veenhuis (1982) developed an algorithm for predicting storm runoff originating from impervious areas based upon data obtained from 14 basins located in Denver, Colorado. Their algorithm is as follows:

$$IRO = 0.0015\ (FIMP*100)^{1.41}*RFa \qquad \text{Eq. 2}$$

Equations 1 and 2 predict surprisingly similar results if the impervious area exceeds about 25 percent. The two equations provide different results if the impervious area is less than about 25 percent because of the 17 percent term in Equation 1. Equation 2 was therefore used in the project model studies to predict the effective runoff producing impervious area for watersheds lightly developed (<20 percent), thereby eliminating the need to estimate the extent of the directly connected areas.

Not all storm runoff originating from impervious surfaces reaches a stream, particularly in areas underlain by soluble carbonate rocks. During small storms much of the runoff originating from roofs, for example, drains across lawns where it infiltrates into the soil. Thus, there are transmission losses of potential runoff originating from impervious surfaces which are inversely related to the size of a storm (i.e., during larger storms pervious areas become saturated and the transmission losses are reduced). The algorithm for handling transmission loss operates as follows:

$$IRO = RFa^2 * 1.165 * (FIMP - 0.17)/TLP \qquad \text{Eq. 3}$$

subject to condition $RFa \leqq TLP$; otherwise Eq 1 applies

where: TLP is a model parameter, in inches of runoff.

In effect, Equation 3 represents a rational approach for calculating reduced runoff originating from impervious areas during smaller storms. The transmission losses are not determined; rather reduced runoff is determined for all storms less than the parameter TLP (with the effect decreasing as TLP is approached). A limited number of tests on data collected during Betson's 1976 study indicated that a TLP value of 1.0 usually produced reasonable results.

The final two algorithms relevant to this study are used to reduce the potential storm runoff originating from pervious areas (PKARST) and the potential baseflow (DLF) when the watershed overlies soluble carbonate rock. Parameters are used in both algorithms, in effect, to reduce the respective potential runoff amounts by a fraction.

$$SURVOL = SURVOL*(1-PKARST) \qquad \text{Eq. 4}$$

$$GWV = GWV(1-DLF) \qquad \text{Eq. 5}$$

where: SURVOL = storm runoff originating from pervious areas, in inches

GWV = Groundwater runoff, in inches

PKARST = A parameter used to reduce storm runoff in carbonate-rock areas

DLF = Deep loss parameter used to reduce groundwater runoff in carbonate-rock areas

The PKARST and DLF parameters have values that range between 0 and 1.0. In watersheds underlain by relatively insoluble rock, a value of zero is used (all the potential runoff will occur). In watersheds underlain by very soluble carbonate rocks, a value of 1.0 is used (no runoff occurs). These parameters are usually equated to the fraction of the basin underlain by soluble carbonate rock although considerable judgment can be involved when moderately soluble carbonate rock geology is involved. Judgment is also involved in determining the DLF parameter for larger watersheds where bedrock solution channels contribute to baseflow through the emergence of springs.

C. The Upper and Lower Sink Study Sites

Two sites, the Upper Sink (US) and the Lower Sink (LS) were instrumented with a raingage and streamgages to provide continuous records in a watershed underlain by soluble carbonate rock. The US site and the LS site were located upstream and downstream, respectively, from a short reach of stream filled with coarse gravel typical of streams in this area. The objective in locating these two sites here was to investigate streamflow dynamics within a watershed completely underlain by carbonate rock.

Table VII-2 summarizes the physical characteristics of these two watersheds and lists the approximate percent of each different geologic formation that underlies the two watersheds. Most of the two watersheds are underlain by units of the Knox Group. The lower portions of the Lower Sink watershed are underlain by the Holston Formation and the Lenoir Limestone. A description of these geologic formations was given in chapter II. There are essentially no confining beds underlying the US and LS watersheds that effectively retard groundwater movement among the different geologic units. Soils in the two watersheds are clayey or clay loam. The thickness of the soils are variable but generally are greater than five feet. The soils characteristically have moderate permeabilities and relatively high water-storage capacities ($\approx$10 inches).

The recorded daily precipitation and the corresponding runoff for water years 1981 and 1982 were shown in tables IV-5 through IV-10. These data are summarized, by months, in

Table VII-2

Characteristics of the Upper and Lower Sink Watersheds

Characteristic	Upper Sink (US)	Lower Sink (LS)
Drainage area, sq. mi.	0.260	0.380
Land cover, percent		
Woodland	23	23
Grassland	54.7	53.4
Gardens	7	8
Impervious	14.3	14.6
Unvegetated	1	1
Geologic formation, percent[a]		
Holston Formation	0	5
Lenoir Limestone	0	2
Mascot Dolomite	18	30
Kingsport Dolomite	22	21
Longview Dolomite	35	24
Chepultepec Dolomite	25	18

a. Approximate percent of a geologic formation that underlies each watershed.

table VII-3. It is evident from the data presented in table VII-3 that the presence of carbonate rocks is influencing the hydrology of these two watersheds. In a year of normal rainfall (45.6 inches), runoff is expected to be about 16 inches if all the potential runoff were to pass the streamgage (Betson, et al, 1980). Table VII-3 shows that even in water year 1982, when rainfall was 8.5 inches above normal, the runoff at both sites was only about 20 percent of the expected normal annual runoff. In addition, runoff is generally less at the Lower Sink site than at the Upper Sink site. This reduction in runoff seems to be most pronounced during months with lower flows. Tables IV-5 to IV-10 showed that the flow is intermittent at both sites and is associated with storm periods.

The continuous daily streamflow model component of the watershed model TVA-HYSIM was used to simulate flows at both gage sites. The purpose in using the model to simulate flows at these two sites was not to demonstrate the capabilities of this particular model under these geologic conditions, but rather to use the model to help explain the hydrology of watersheds underlain by soluble carbonate rock. Therefore, no particular effort was made to optimize the model parameters. The internal regionalized relationships were used to predict the model parameters from watershed measures. The three carbonate-rock associated parameters (described in Section B of this chapter) were set based upon best estimates from

Table VII-3

Monthly Precipitation and Runoff Data
Upper and Lower Sink Sites

(all values are inches)

		Month												
Location	Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
							1981[a]							
	RF			1.88[b]	0.91	3.76	2.90	3.67	2.72	4.92	4.85	3.90	4.27	33.78
US	RO			0.01[b]	0	0.10	0.04	0.06	0.05	0.58	0.22	0.05	0.13	1.24
LS	RO			0[b]	0	0.02	0	0	0.05	0.60	0.07	0.05	0.16	0.95
							1982							
	RF	4.11	2.89	4.21	6.47	4.63	5.42	2.66	3.27	3.51	9.44	3.77	3.76	54.14
US	RO	0.08	0.05	0.15	0.63	0.32	0.35	0.06	0.07	0.07	1.04	0.32	0.22	3.36
LS	RO	0.06	0.02	0.10	0.61	0.39	0.36	0.04	0	0.01	1.32	0.21	0.12	3.24

US = Upper Sink
LS = Lower Sink

a. partial year records
b. records begin

inspection of the data. Observed rainfall was used for the simulations. The values used for the three carbonate-rock associated parameters as well as the observed and simulated monthly runoff values for both sites are shown in table VII-4.

The model simulation results which are shown in table VII-4 indicate that these simulations are in the range of the observed data. The simulated annual runoff values are comparable with the observed runoff values, although the model tends to oversimulate some of the months with little flow and undersimulate a few of the higher-flow months. A daily streamflow model will, in general, undersimulate when occasional large high-intensity summer thunder showers occur.

By using a value of 1.0 for the deep loss parameter DLF, all the potential baseflow generated by the model was, in effect, lost and did not appear in the simulated output flows. Therefore, based upon the simulations for the two water years, there was a drainage of potential baseflow into the carbonate-rock solution cavities that averaged almost 10 inches per year (some three times the observed flow).

The parameter PKARST controls the amount of storm runoff which will be generated from pervious areas within a watershed. This parameter was set to 0.75 which means that 25 percent (100-75) of the potential storm runoff generated by the model appears in the simulations. The remaining 75 percent of storm runoff generated by the model (which averaged some three inches per year) seeps into the soil/rock system.

Table VII-4

Monthly Observed and Simulated Runoff
Upper and Lower Sink Sites

(all values are inches)

Location	Type	Month Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
							1981							
US	Obs			0.01[a]	0	0.10	0.04	0.06	0.05	0.58	0.22	0.05	0.13	1.24
US	Sim			0.09	0.01	0.15	0.14	0.10	0.05	0.22	0.19	0.09	0.20	1.23
LS	Obs			0[a]	0	0.02	0	0	0.05	0.60	0.07	0.06	0.16	0.95
LS	Sim			0.08	0.01	0.13	0.13	0.08	0.04	0.22	0.16	0.07	0.20	1.11
							1982							
US	Obs	0.08	0.05	0.15	0.63	0.32	0.35	0.06	0.07	0.07	1.04	0.32	0.22	3.36
US	Sim	0.13	0.07	0.14	0.39	0.31	0.47	0.11	0.08	0.07	1.19	0.20	0.19	3.35
LS	Obs	0.06	0.02	0.10	0.61	0.39	0.36	0.04	0	0.01	1.32	0.21	0.12	3.24
LS	Sim	0.10	0.05	0.12	0.35	0.29	0.44	0.10	0.07	0.06	1.14	0.19	0.19	3.11

a. records begin

Carbonate Rock-Associated Parameter Values Used

Parameter	Value US	LS
TLP	1.5	2.0
DLF	1.0	1.0
PKARST	0.75	0.75

The third carbonate-rock associated parameter is TLP, which controls transmission losses of runoff from impervious areas. These losses are largest (percentage-wise) during smaller storms and decrease as the amount of storm rainfall approaches the value of the parameter TLP. This parameter is typically set at 1.0 inch. Normally when the storm rainfall exceeds about one inch, soil conditions become sufficiently saturated that no runoff originating from impervious areas is lost by percolating into pervious areas. It was found necessary to use TLP values of 1.5 to 2.0 inches at the upper and lower sink sites, respectively. Equation 3 showed how the TLP parameter is used in the model to predict impervious area runoff. The need to increase TLP values at these watersheds higher than the typical one-inch value indicates that transmission losses are higher in these two watersheds, which consequently reduces impervious area runoff.

The results shown in table VII-4 indicate that the simulated runoff is often somewhat higher than the observed data, particularly during drier months. This means that transmission losses are probably even higher than the model simulated. The TLP parameter values could have been increased in an attempt to decrease the simulated values during low-flow months; however, to keep the annual simulated runoff approximately equal to the observed runoff would have necessitated decreasing the parameter PKARST (which serves to increase the storm runoff from pervious areas). Whether or not these fine-tuning changes would markedly improve the simulations was not investigated since the purpose in this phase of the study was to use the model as a tool for interpreting the hydrology of watersheds in areas of soluble carbonate rock.

The following observations and conclusions can be drawn about the hydrology of watersheds underlain by soluble carbonate rock based upon the rainfall-runoff data shown in table VII-3 and the modeling results shown in table VII-4:

1. More of the storm runoff originating from impervious areas will be lost during transmission as it travels over pervious surfaces or permeable reaches in the channel.
2. Less of the potential storm runoff from pervious surfaces will occur.
3. All or most of the potential baseflow of a stream can be lost through drainage into the soluble carbonate-rock system.
4. When the water table is high during wet periods (January through March 1982) greater amounts of runoff occur. Apparently there is a reduction in the transmission losses; however, the runoff still does not approach that in watersheds underlain by noncavernous rock.
5. Large summer storms can result in relatively heavy runoff; nevertheless, the reasonable simulations for the storm of July 31, 1982 (4.17 inches of rainfall) indicate that much of the potential runoff will still drain into carbonate rocks.

Essentially the drainage system in soluble carbonate rock can be visualized as operating in much the same way as tile systems which are used to drain wetlands. Much of the potential runoff drains through cavities with the portion lost to the cavities related to the efficiency of the drainage system (or solubility of the rock). Runoff at these two watersheds typically decreases between the Upper and Lower Sink sites. It is apparent that the rock formations underlying the portion of the watershed below the Upper Sink site (including the stream reach between the gages) is more soluble than the formations under the Upper Sink watershed. In very soluble formations where large cavities exist (as appears to be the case in the lower watershed), "dry valleys" can occur (Gregory and Walling, 1973) and runoff is only in response to infrequent, heavy storms which exceed the infiltration capacity of the soil. In areas where solution cavities are less efficient drains, more of the potential runoff will occur as streamflow.

Although no studies were made to determine where the potential runoff lost to the carbonate rock system from these two watersheds ultimately reappears, the geology indicates that it drains into an adjoining basin. The Upper Sink watershed is underlain by rocks of the Knox Group and the Lower Sink watershed is underlain by the Lenoir Limestone and the Holston Formation. The Holston Formation is one of the more soluble rock units in the Knoxville area as evidenced by a large number of penetrable caves per square mile. The Knox Group (particularly the Mascot Formation, which is in the Lower Sink watershed) is second in the number of caves only to the Holston (Moore, 1973). Caves are common when the Lenoir Limestone is in stratigraphic contact with the Holston Formation. Thus, while all the formations underlying these two study watersheds are soluble, the most soluble are in the lower watershed area. This can account for the decrease in runoff between the US and LS sites.

The two watersheds are located near the longitudinal axis of a syncline. The formations underlying these watersheds dip southeast toward the axis of the syncline and the syncline plunges northeasterly toward the adjoining First Creek watershed. Since there are no effective confining beds that would retard groundwater movement among the underlying formations, drainage in these formations could potentially be toward First Creek with the most effective drainage through cavities in the more soluble Mascot, Lenoir, and Holston units. A trend of sinkholes along the outcrop area of the Mascot, Lenoir, and Holston units indicates increased bedrock solubility. There are a number of large springs feeding First Creek which flow from these same rock units.

D. Model Studies at the Four Water Quality Study Watersheds

The hydrologic model TVA-HYSIM was used to simulate continuous daily streamflow values at each of the four study watersheds

(R1, R2, SC, and CBD sites) for the two water years 1981 and 1982. Observed daily rainfall values were used for the simulations. Model parameters were computed using the internal regionalized relationships from read-in measures of land cover, long-term mean rainfall (45.6 inches), expected long-term evapotranspiration (29.5 inches), and the available water holding capacity of soils (10.5 inches).

The observed stormflow data at the four study watersheds consist of storm rainfall and the associated runoff. For each storm for which observed rainfall-runoff data were available, the corresponding rainfall and associated simulated runoff were obtained from the program printout. In most cases the storms were sufficiently isolated so that a storm corresponding with an observed event could be identified in the daily values.

Table VII-5 lists the results obtained from these modeling studies. The table shows the relevant model parameter values and the size of each drainage area. The table shows the average 1981-1982 rainfall, total runoff, runoff from impervious areas, and the losses of potential runoff bypassing the respective gage site.

The simulated runoff shown in table VII-5 indicates that the carbonate rock is exerting a considerable influence on streamflow at these sites. Based upon studies of annual runoff in this region (Betson, et al, 1980), the expected long-term

Table VII-5

Summary of Modeling Studies at Four Knoxville Sites

Measure	Residential Site R1	Residential Site R2	Strip Commercial SC	Central Business District CBD
Parameter FIMP	0.317	0.134[a]	0.428	0.99
Parameter PKARST	0.75	0.90	1.0	0.0
Parameter DLF	1.0	1.0	1.0	1.0
Parameter TLP	3.0	0.0	1.0	0.0
Drainage area, sq. mi.	0.110	0.140	0.290	0.017[b]
Model Results-Average for Water Years 1981-1982				
Rainfall, in.	50.7	47.7	47.1	44.6
Total runoff, in.	3.8	3.1	8.9	25.7
Impervious area runoff, in.	2.7	2.5	8.9	25.7
Bypass loss, in.	14.8	13.1	7.7	1.3
Storm Runoff Simulations vs Observed				
Number of storms	14	13	16	17
Average storm rainfall, in.	0.89	0.89	0.69	0.63
Average simulated storm runoff, in.	0.062	0.058	0.12	0.56
Average observed runoff, in.	0.060	0.057	0.12	0.56
Linear regression X=Obs; Y=Sim.				
Intercept	0.013	0.010	-0.03	-0.004
Slope	0.831	0.848	1.29	1.006
Correlation coefficient	0.60	0.92	0.90	0.96
Simulated Yield (runoff-rainfall)	0.067	0.065	0.17	0.89

a. Equation 2 used to determine directly connected area.
b. Effective area draining to sewer based on analysis of runoff data.

average annual runoff should be about 16 inches (long-term rainfall less expected evaportranspiration losses; 45.6 less 29.5 equals 16.1). Since average rainfall for the two-year period of record approximated the long-term average, the expected runoff for these watersheds should also be about equal to the long-term average. Table VII-5 shows that at three of the watersheds the simulated runoff was considerably less than the expected value with most of the runoff coming from impervious areas. Only at the CBD site, where there is little opportunity for either evapotranspiration or bypass losses (since drainage from impervious areas is by sewer), is the simulated runoff value higher than the long-term mean. Bypass losses of potential runoff into and through the carbonate-rock drainage system account for much of the runoff which could be expected at the other three sites.

The remaining information in table VII-5 summarizes the studies in which storm runoff was simulated by using the model. Shown are: the number of storms; average observed storm rainfall; average simulated storm runoff; average observed storm runoff; the results obtained fitting a linear regression equation between the observed runoff (x) and the simulated runoff (y); and the runoff ratio. The results show that the average simulated and observed storm runoff values are very close which lends credibility to the interpretations of the runoff simulations explained in previous paragraphs.

The results obtained using a linear regression at the two residential sites (R1, R2) and the Strip Commercial site (SC) indicate that even though average simulated and observed storm runoff volumes are similar, the relationships are biased (slope ≠1.0) and/or the correlation coefficient is low indicating the individual storms are not predicted very well. There is probably a number of reasons for the differences between the observed and simulated values including measurement errors, inconsistencies in defining the beginning and end of a storm, and problems inherent in using the daily streamflow model to predict runoff where short-term rainfall intensities are important. However, probably a more important factor which tends to magnify the apparent differences is the fact that storm runoff at these three sites is only a small fraction of the total storm rainfall. In general, the simulated results tend to more closely emulate observed runoff as the size of the impervious area increases. The simulation results obtained at the CBD site correspond closely with the observed data. However, it was found necessary to change the size of the drainage area to achieve these results. The CBD gage site is located in a storm sewer which is part of an old sewer system draining downtown Knoxville. The drainage area was determined from topographic maps and by mapping of observable sewer lines: however, there is no assurance that other sewer lines outside the topographic divide do not also drain into nearby First Creek. Model results suggest that this indeed may be the case.

There are a number of observations which can be drawn from the results of these simulations concerning the effects of drainage into carbonate-rock systems on the hydrology of urban area: (1) little of the potential storm runoff originating from pervious areas within the watershed will occur as streamflow (although the rock underlying the CBD watershed is relatively impermeable, there is only an insignificant pervious area available); (2) transmission losses may be insignificant where only directly connected areas are involved (R2 results); (3) transmission losses tend to decrease as the impervious area percentage increases; (4) the runoff coefficient, in general, will be related to the extent of impervious area but can be quite variable, i.e., lowest in those watersheds underlain by soluble carbonate rock, higher in watersheds underlain by less soluble rock.

E. Groundwater Tracer Study

In areas underlain by carbonate formations, it is difficult to assess the impact that the transport of contaminants through bedrock solution cavities may have on the quality of surface-water bodies. The first two steps in assessing these potential surface-water impacts are to identify the contaminant source and to determine where groundwater emerges from fractures or cavities (springs) into surface-water bodies. Controlled tests are needed to determine the amount of dispersion of the groundwater contaminants between the source of pollution and the emergent points.

It was postulated that the water quality of Second Creek might be affected by the groundwater transport of contaminants from an adjoining watershed. A groundwater tracer study was conducted for the following reasons: (1) to gain an increased understanding of groundwater flow through cavities in carbonate rock; and (2) to determine whether runoff entering a sinkhole in a mature karstic area reappears in a surface-water body in the same watershed or an adjoining watershed.

Location and Size

The groundwater tracer study was conducted in the Murphy Creek area of the First Creek watershed, which is northeast of Second Creek watershed (figure VII-1). In the Murphy Creek area, numerous sinkholes and disappearing streams characterize the valley underlain by carbonate-rock formations. The size of the First Creek watershed is approximately 22 square miles. The topography and climate are similar to that in Second Creek.

Geohydrologic Conditions

In general, the First Creek watershed is underlain by consolidated sandstone, shale, limestone, and dolomite that range in geologic age from Early Cambrian to Middle Ordovician. The

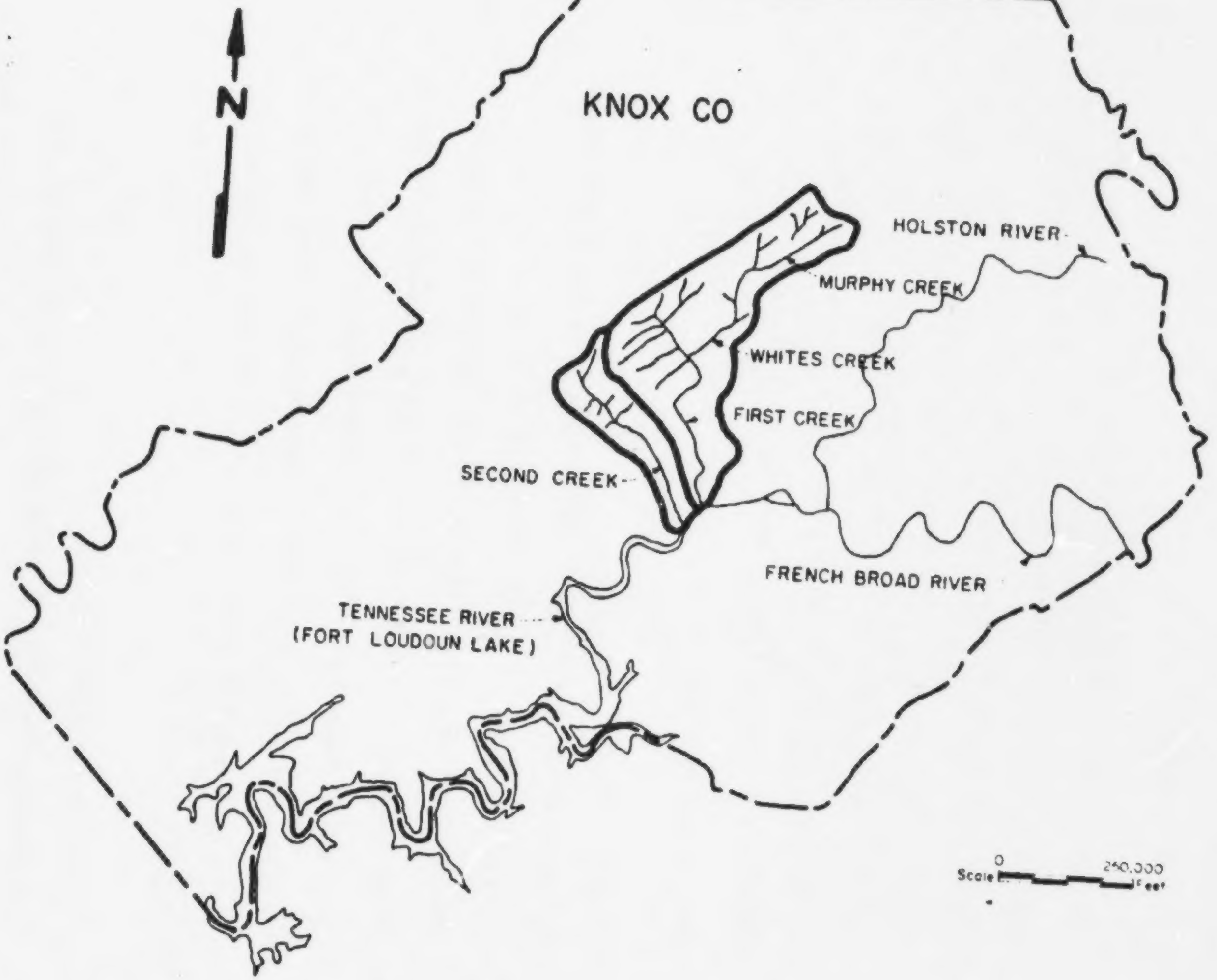

N
KNOX CO
HOLSTON RIVER
MURPHY CREEK
WHITES CREEK
FIRST CREEK
SECOND CREEK
FRENCH BROAD RIVER
TENNESSEE RIVER
(FORT LOUDOUN LAKE)
Scale
0
250,000
Feet

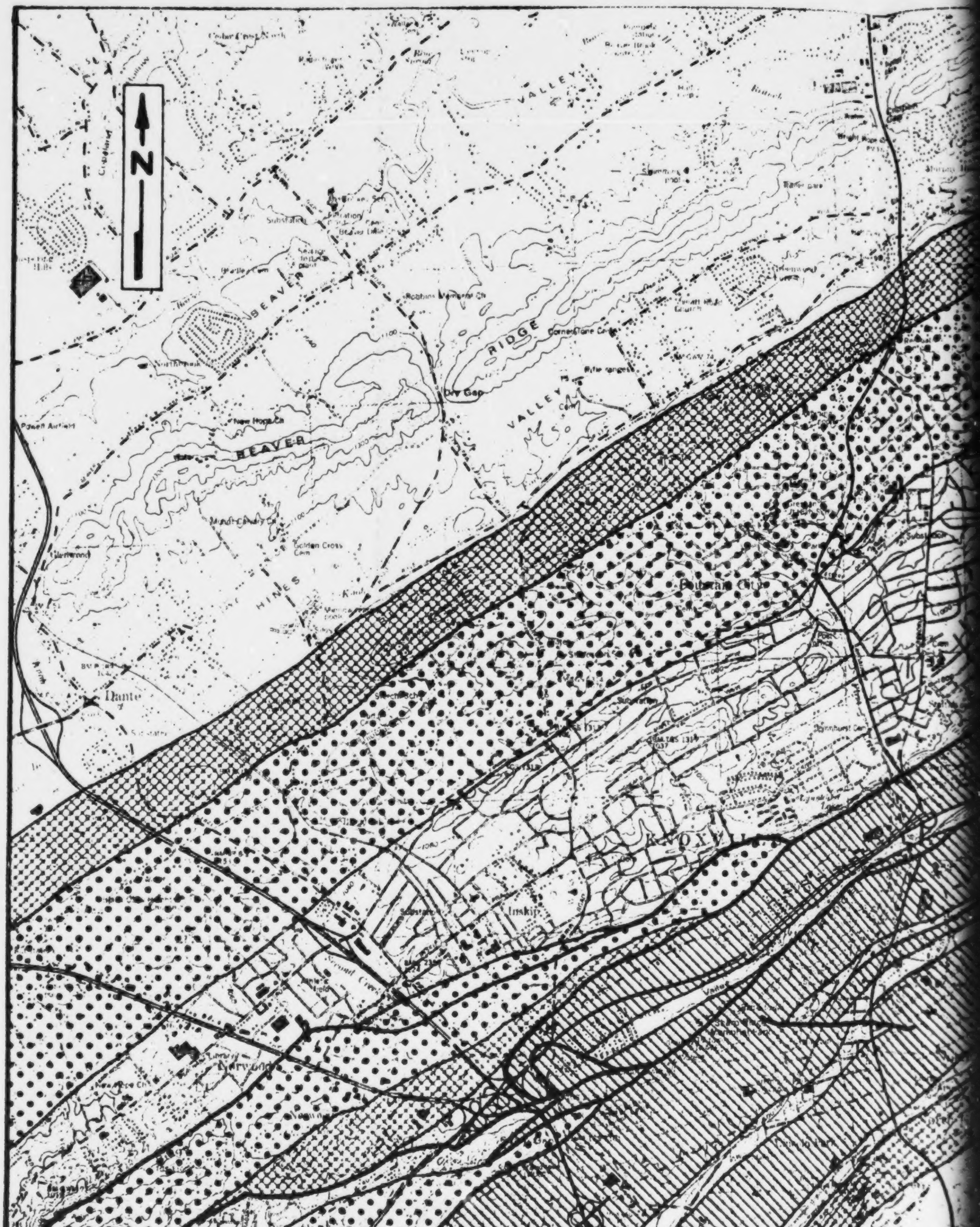
Figure VII-1 First Creek and Second Creek Watersheds, Knox County, Tennessee

ridges and rolling hills are upheld by resistant units of sandstone and noncalcareous shale; whereas, the valleys are underlain by more soluble units of limestone, dolomite, and calcareous shale.

Groundwater is recharged by precipitation that enters the subsurface by either seeping through the pore spaces in the soil or directly through openings in exposed bedrock. Sinkholes and disappearing streams are point sources of recharge to the groundwater system. Runoff originating on steep slopes and in higher elevation areas drains into sinkholes in the Murphy Creek area valley.

Groundwater occurs in the fractures, joints, and along bedding planes of the bedrock. In the soluble carbonate formations, these openings have been enlarged by circulating groundwater to create solutional cavities (or large voids in the bedrock) which have a large storage capacity. The relatively impermeable sandstones and shales that underlie the ridges and rolling hills in the area usually have small storage capacity and carry a smaller amount of water than the more soluble carbonate formations.

The predominant water-bearing characteristics of a geologic unit in its outcrop area can be used to define geologic units as regionally or locally significant aquifers or regionally or locally effective confining beds. Figure VII-2 illustrates


N
BEAVER
RIDGE
VALLEY
BEAVER
VALLEY
RIDGE
HINES
KNOX
Dry Gap
Dante
Inskip
Norwood
Fountain City
Golden Cross Cem
New Hope Ch
Northbrook
Cornerstone Ch

A

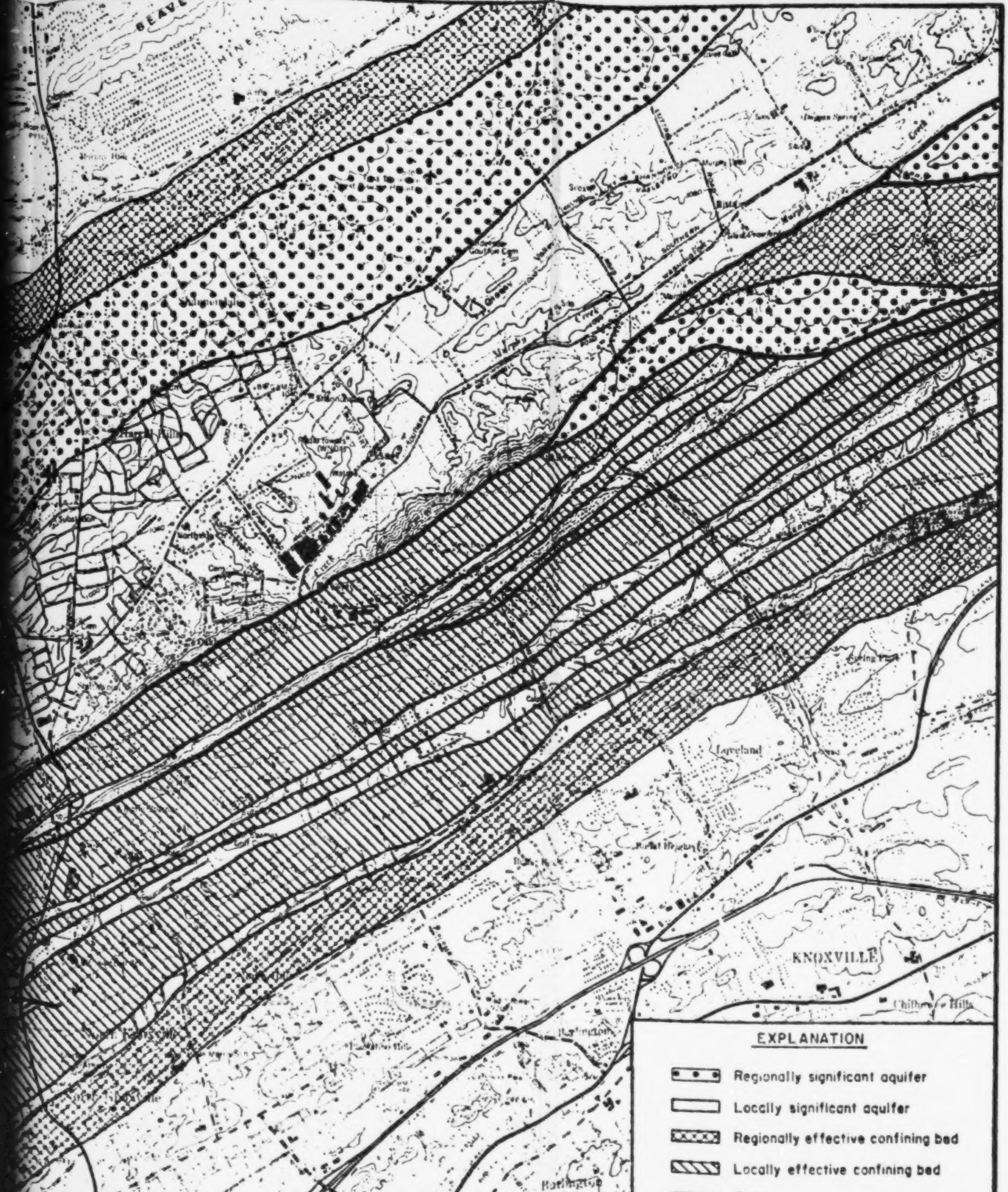

EXPLANATION
Regionally significant aquifer
Locally significant aquifer
Regionally effective confining bed
Locally effective confining bed
Fault
KNOXVILLE
Loveland
Chilhowee Hills

Figure VII-2 Groupings of Geologic Units with Similar Water-Bearing Properties

B

150a

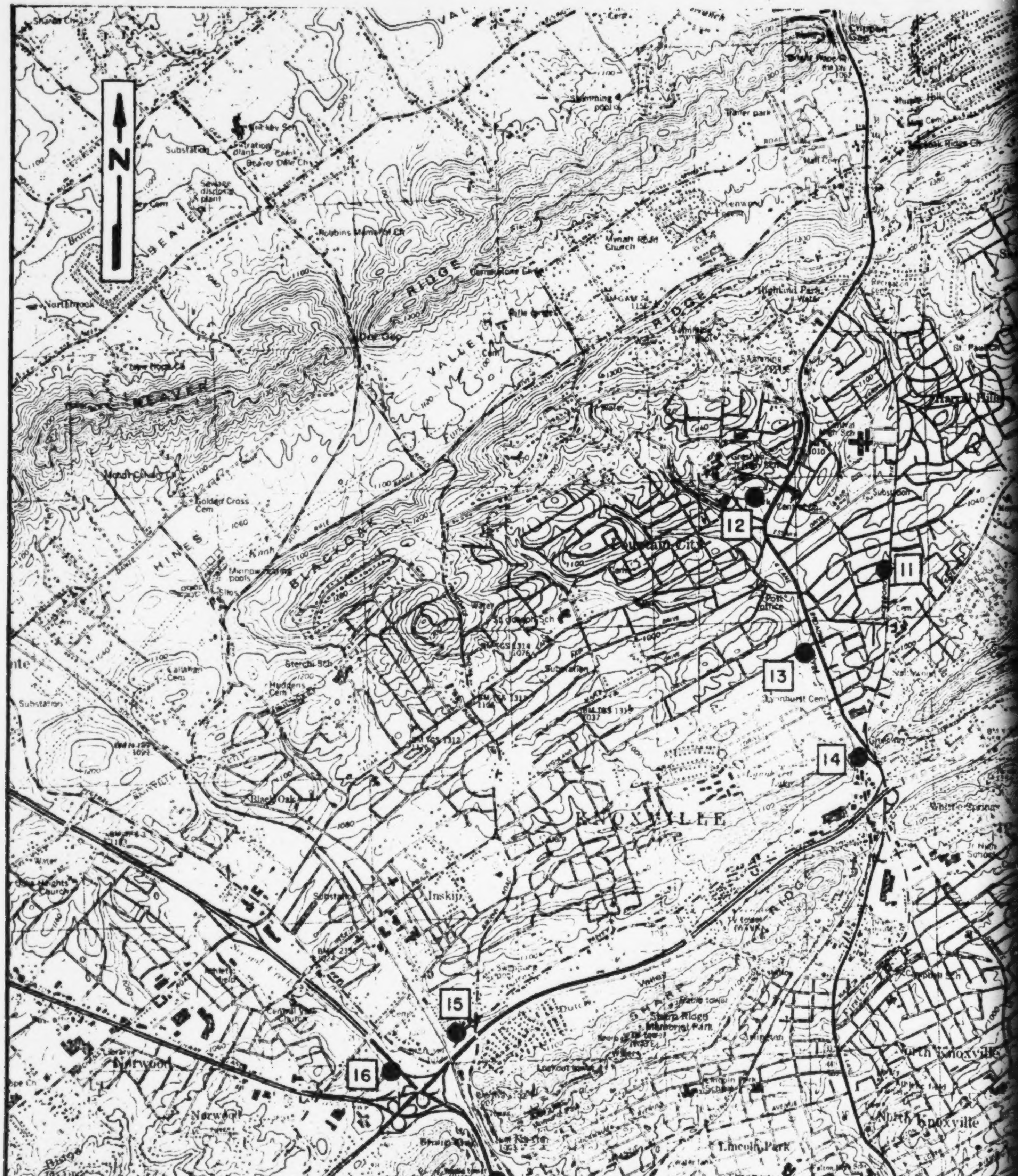
the groupings of geologic units in the tracer test study area with similar water-bearing properties. There can be local variations in the water-bearing properties of geologic units due to facies changes or structure-related effects.

Procedure

The tracer material used in this study was Rhodamine WT dye (20 percent solution). This nontoxic dye was chosen because of its high detectability, low sorptive tendency, good diffusivity, low acidity, and that it is recommended for applications requiring a high percentage recovery of dye (Wilson, 1968).

The dye-injection site, or sinkhole (figure VII-3) was chosen for the following reasons: (1) the sinkhole was a direct connection between land surface and underlying bedrock, (2) the sinkhole was not plugged with sediment or debris, and (3) 1.5 to 1.9 cfs (675 to 850 gal per minute) of groundwater flowed through the cavity system at the bottom of the sinkhole. Therefore, the initiation of the tracer test was not directly dependent upon a rain event. The sinkhole occurs in the Holston Formation, a predominant cave-forming geologic unit in Knox County (Moore, 1973). A description of the Holston was given in chapter II.

A method similar to that used by Gann and Harvey (1975) was used to monitor the possible emergent points of the dye after injection.


N
BEAVER
BEAVER
RIDGE
VALLEY
RIDGE
BLACK OAK
HINES
Fountain City
KNOXVILLE
Inskip
Norwood
Norwood
Black Oak
Sharp Ridge Memorial Park
Lincoln Park
North Knoxville
North Knoxville
Substation
Robbins Memorial Ch
Golden Cross Cem
Sterchi Sch
St Joseph Sch
Lynnhurst Cem
11
12
13
14
15
16
17

A

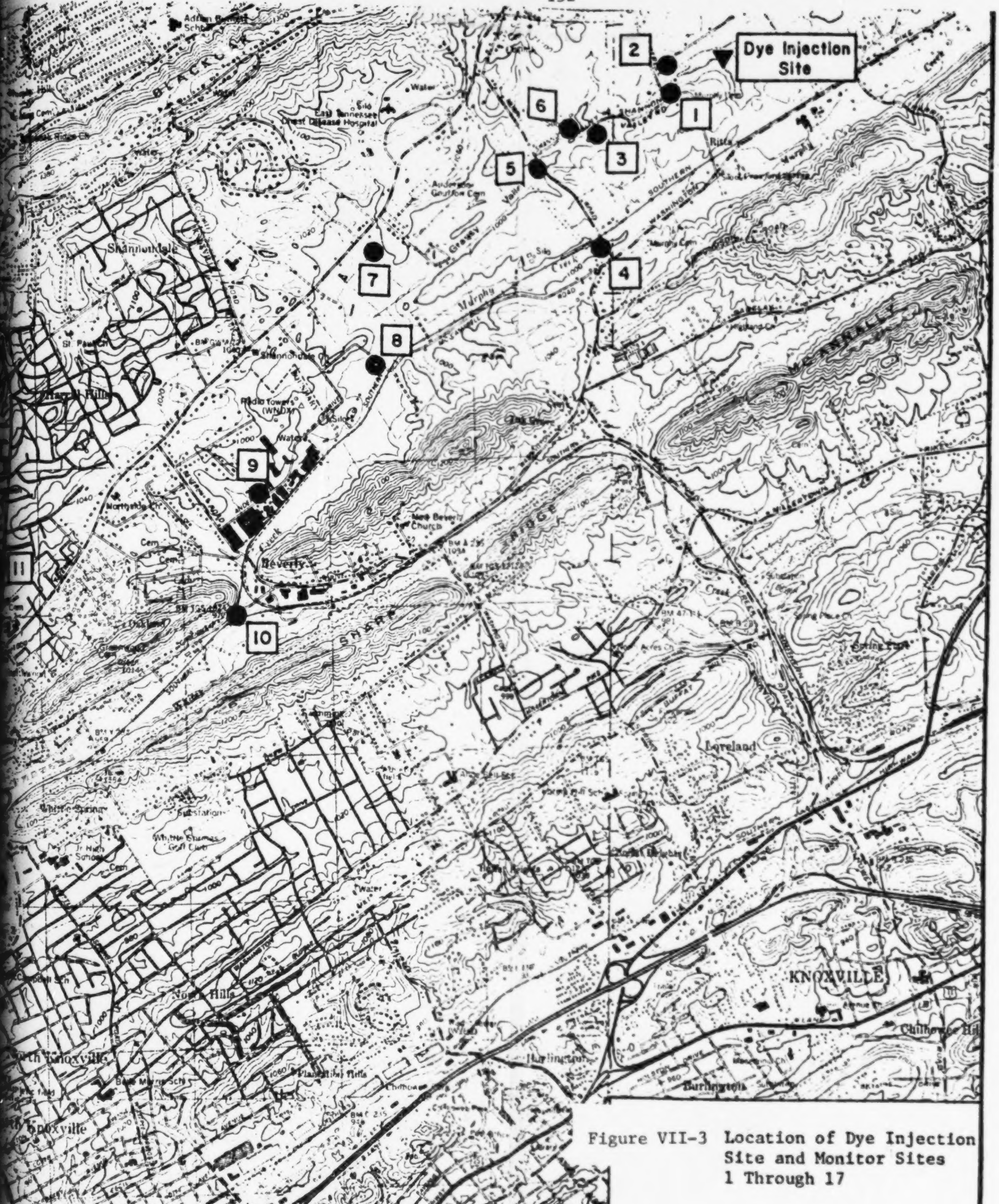

Dye Injection Site
1
2
3
4
5
6
7
8
9
10
11
BLACK OAK
East Tennessee Chest Disease Hospital
Shannondale
Radio Towers (WNOX)
Beverly
New Beverly Church
SHARP
RIDGE
McANNALLY
Murphy Creek
Loveland
KNOXVILLE
Chilhowee Hills
Burlington
North Hills
Whittle Springs
Whittle Springs Golf Club
SOUTHERN

Figure VII-3 Location of Dye Injection Site and Monitor Sites 1 Through 17

152a

B

Nylon stockings containing 40 grams of activated charcoal granules to absorb the dye were placed in springs, streams, and a sinkhole where the dye was likely to reappear in the First and Second Creek watersheds. The monitoring sites were located in the Holston Formation, soluble units of the Knox Group (geologic description given in chapter II), or along faults. Figure VII-3 shows the location of 17 sites which were monitored, including three domestic wells, four springs, one sinkhole, and nine stream locations. The streams were monitored in several locations in case the dye had flowed around the charcoal packet placed at a spring's discharge point or if water-filled bedrock fractures fed the streams downstream from the spring. Charcoal filter cartridges were inserted in water well plumbing where dye was likely to enter a domestic well. These monitoring sites were selected on the basis of the following: (1) strike and fracture trends of the geologic formation, (2) generalized groundwater flow patterns (Kung, 1980), (3) sinkhole and cave distribution in Knox County (Harris, 1973 and Moore, 1973), and (4) the water-bearing characteristics of the geologic units (see figure VII-2) and geologic structure. The charcoal packets were analyzed for presence of dye several times during the test period and were replaced with new packets at each sample collection. In the laboratory, the charcoal was elutriated with a five percent solution of ammonium hydroxide in ethyl alcohol for two hours.

After filtering, the solution was tested for presence of the dye with a Turner Model 10 fluorometer.

Two days prior to the injection of the dye, water samples were collected at each monitoring site and were analyzed for background fluorescence. Natural fluorescent material, caused by vegetative growth or decaying organic matter, can occur in streams and springs. The concentration of natural, or background, fluorescent material at each of the 17 monitoring sites ranged from 0.017 to 0.08 parts per billion (ppb).

On April 28, 1982, a dye concentration of 336 ppb was pumped into the sinkhole at the rate of 276 ml per minute for a 3-hour period. The charcoal packets were collected from each monitoring site and were analyzed for the presence of dye from April 28 through June 9.

Interpretation of the Results

Fluorescence was detected at 9 of the 17 monitoring sites. Dye was detected at five of these nine sites. The concentrations of dye ranged from 0.1 ppb to 97.0 ppb. At four of the nine sites, it is believed the fluorescence was not representative of Rhodamine WT dye primarily because of the amount of dilution which occurred before the dye could have reached these sites. At the eight remaining monitor sites, less than 0.1 ppb of fluorescent material was detected.

Conclusions

The following conclusions were drawn from the results of the groundwater tracer study:

1. There does not appear to be an interbasin transfer of groundwater between the Murphy Creek and Second Creek watersheds. Therefore, runoff in the Murphy Creek area is unlikely to affect the water quality of Second Creek.
2. The fracture network of the carbonate formations affects the direction of groundwater flow (or contaminants) from points of recharge to areas of discharge. The direction of groundwater flow in the upper First Creek drainage basin tends to follow the direction of strike, northeast-southwest. It is also possible that groundwater flow follows joints perpendicular to strike, which could account for dye being detected in a groundwater well (site No. 2) located perpendicular to the strike of the injection cave system. According to Moore (1973), caves in the formation (in which the dye was injected) generally elongate parallel to strike joints; however, the shorter connecting passages follow the direction of dip (joints perpendicular to strike).
3. Drainage of stormwater into sinkholes can be a probable source of groundwater contamination to water wells drilled in karst formations.

VIII. Water Quality Mass Balance

Previously, in section VII, it was shown that the soluble carbonate geology within the four water quality study areas influenced a loss of potential runoff within each of these subbasins. This loss of runoff[1] as a result of infiltration into the soil/rock system was found to be variable among the four catchments, and was dependent upon the percentage of impervious area within each basin.

The CBD, for example, had the lowest runoff losses and contained the highest percentage of impervious area. The SC, R1, and R2 catchments had progressively higher amounts of runoff losses and contained, respectively, lower percentages of impervious area. This can be shown hierarchically where:

For runoff losses: CBD<SC<R1<R2
For percent impervious area: CBD>SC>R1>R2

The above findings suggest that potential pollutant loading in Knoxville's urban runoff may be affected by the carbonate geology of the area. In order to evaluate this aspect of urban runoff, a mass balance was calculated for each runoff event and its associated storm and antecedent dry period. The total atmospheric mass input of constituents preceeding a runoff event was determined from the dryfall and wetfall data collected during the intervals between successive runoff events. This total atmospheric input (dryfall plus wetfall) mass was divided by the total

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[1] Runoff loss is the volume of water that is unaccounted for in the surface runoff and is assumed through a predictive model to have entered the carbonate rock solution channel drainage system.

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mass (load) of a constituent in the runoff associated with the preceding atmospheric input interval. The resulting storm input-output load ratio enables an assessment of the influence of carbonate geology on urban runoff loads. For example, ratios greater than unity indicates that atmospheric input exceeds runoff output, suggesting the retention of mass within the basin or loss through the carbonate geology. Ratios less than unity indicate that runoff output exceeds atmospheric input, suggesting a contribution of mass by the drainage basin to the runoff load.

In table VIII-1, the mean of the ratios of the atmospheric input loads to the storm runoff loads are given for all storms sampled in the CBD, SC, R1, and R2 subbasins. The most significant aspect of the data in this table is that among the four subbasins the input/output ratios progressively increase such that in general: CBD<SC<R1<R2. This hierarchy holds for most constituents and suggests a direct causative relationship with the previously established runoff losses to the groundwater, and an inverse relationship to the percentage impervious area in the subbasins. For example, runoff losses are lowest for the CBD catchment because of the high percentage of impervious area, while runoff losses in the R2 catchment are highest due to the lower percentage of impervious area. Consequently, mean input/output load ratios are lowest in the CBD and highest in the R2 basin. The retention of mass within a basin during a storm event may be a result of infiltration and subsequent entrapment or adsorption in the soils, or it

Table VIII-1

Mean Ratios of Atmospheric Input Loads (Wet and Dry) To Storm Runoff Loads for Storms Sampled in the Second Creek Basin

Constituent	CBD	SC	R1	R2
TDS	0.51	1.1	2.3	5.3
TSS	0.12	0.27	0.53	1.7
TKN	2.0	1.7	4.3	9.8
TP	0.33	0.17	0.43	2.6
NO_2+NO_3	2.2	19.4	12.9	23.9
TOC	1.2	2.0	6.8	13.6
COD	1.0	1.4	5.7	8.9
K	0.16	0.24	0.48	1.5
Ca	0.09	0.06	3.2	0.42
Mg	0.10	0.35	0.50	0.76
Na	0.95	0.86	4.6	9.7
Cl	1.0	0.79	2.7	19.9
SO_4	1.8	1.5	9.0	31.4
Fe	0.15	0.18	0.33	1.0
Mn	0.31	0.23	0.25	1.5
Cu	4.1	7.9	9.1	100.4
Zn	0.77	0.51	2.2	4.6
Cr	0.21	3.4	13.7	11.8
Se	4.1	4.1	17.3	27.1
Hg	10.8	59.2	28.0	85.0
Ni	3.8	4.1	17.3	27.1
Cd	3.7	2.8	36.3	60.8
Pb	0.46	0.17	0.82	1.3
Al	0.27	0.34	0.34	1.3

may be the result of loss to the groundwater through surface connected solution channels. In the CBD subbasin the high percentage of impervious area prevents the access of storm runoff to the soil or solution channels; consequently, the input/output ratios are much lower than those for the R1 and R2 subbasins where access is less restrained by large impervious areas.

Whether significant portions of urban runoff pollutants are lost to the groundwater or are merely retained within the soils of the Second Creek basin is difficult to determine without a direct measurement of groundwater quality. However, indirect measurements have provided an abundance of circumstantial evidence to conclude that significant quantities of the pollutants in Knoxville's urban runoff are entering the groundwater. This evidence includes:

(1) Mass balance data from a 1976 report (Betson, 1976) which showed an accumulation of atmospheric pollutants (input/output load ratio >1.0) within a Knoxville area watershed (Plantation Hills) that is geologically similar to the Second Creek basin.

(2) Mass balance data acquired during this study indicates a large portion of urban runoff load is retained within study watersheds which are underlain by soluble carbonate rock and are lightly developed.

(3) Hydrological modeling in this study indicates that significant losses of urban runoff to the groundwater occurs above that which would be retained as soil-moisture.

In addition, further analysis of data from the R2 subbasin, where the largest runoff losses would be expected, showed high positive correlations between the input/output ratios of conservative constituents, such as potassium, sodium, chloride, and sulfate, and antecedent dry days. This would reasonably imply that during the season of high intensity, short duration rainfall, and longer antecedent dry periods, the groundwater table would be low and recharge by urban surface runoff would readily occur, carrying with it the relatively nonreactive elements. This hypothesis operates following the premise that generally storms of high intensity are of short duration and low intensity storms are of long duration. Indeed, there is a negative correlation between intensity and duration ($r = -0.64$) for storms during the study period.

The seasonal nature of the magnitude of urban runoff losses to the groundwater is further evidenced by the change in the input/output ratios of individual storms during the study period. For example, historically during January, February, and March the greatest amount of precipitation occurs in the study area which results in relatively saturated soil conditions and a high water table. Under these circumstances the amount of runoff leaving a watershed, such as the R1 and R2 subbasins, represents a higher percentage of the input to the basin; consequently, rainfall/runoff load ratios are low. Conversely, during September, October, and November, the driest months of the year, soils are usually far below saturation and the water table is depressed, resulting in a smaller percentage of the runoff leaving the basin through surface runoff and a greater accumulation of pollutants. Under these latter circumstances, the rainfall/runoff load ratios are at an annual high. The seasonal fluctuation in load ratios at the R1 and R2 study sites is shown in table VIII-2. The table presents the average rainfall/runoff load ratios for the three months of the year with the greatest and least precipitation. The data indicates that nearly all constituents have larger load ratios during the dry months, and smaller ratios during the wet. This additional information provides further evidence with which to conclude that pollutants in urban runoff from the R1 and R2 subbasins either accumulate in the soils or enter the groundwater in significant quantities.

Table VIII-2

Average Rainfall/Runoff Ratios During Wet Months (January-March) and Dry Months (September-November) in the R1 and R2 Subbasins

	R1		R2	
Constituent	Wet months	Dry months	Wet months	Dry months
TDS	0.5	1.9	2.0	4.1
TKN	3.0	3.4	5.1	18.0
TP	0.3	0.2	0.5	10.2
NO_2+NO_3	6.7	2.4	25.5	15.3
TOC	0.8	1.8	5.1	5.6
COD	0.4	1.3	1.4	6.9
Ca	0.6	0.3	0.07	0.1
Mg	0.1	0.4	0.1	0.7
Fe	0.02	0.7	0.5	1.6
Mn	0.1	0.3	0.4	1.7
Cu	15.9	4.5	47.3	9.6
Zn	0.5	3.2	2.1	4.7
Cr	0.3	3.9	1.4	8.8
Hg	-	-	8.5	12.7
Cd	0.7	6.5	3.0	20.3
Pb	0.1	0.8	0.6	1.2
Al	0.02	0.3	1.5	1.8

IX. Conclusions

The data acquired during the study was analyzed so that three aspects of urban runoff could be evaluated, (1) the effect of land use on urban runoff quality and quantity, (2) the effect of carbonate geology on urban runoff quantity, and (3) an integrated evaluation of the effect of carbonate geology on urban runoff quality and quantity. The following conclusions related to these aspects, based on the data analysis in this report, are summarized under these three categories.

1. Characterization of urban runoff quality and the effect of land use.

   - Urban runoff samples from commercial and residential land use areas were found to contain concentrations of copper, chromium, iron, zinc, cadmium, and lead that exceeded either EPA's Drinking Water Standard or aquatic toxicity level in terms of their event mean concentration and/or geometric mean. However, only lead and iron concentrations were found to exceed their toxicity levels during a significant percentage of runoff events. This study indicates that lead and iron are the metals of concern in Knoxville's urban runoff.
   - In terms of load, the data suggest that in areas underlain by carbonate rock, in drainages containing high percentages of impervious area, such as the CBD and SC subbasins, the urban runoff will generally have a higher pollutant load, in terms of mass per unit area, than basins with a low percentage of impervious area, such as the residential basins.

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- In general, suspended and dissolved solids, COD, aluminum, iron, zinc, lead, and manganese were found to be relatively high-load runoff constituents, while alkalinity, calcium, BOD_5, total and soluble organic carbon, sulfate, nickel, and copper could be classed as moderate load constituents, and magnesium, potassium, nitrate, chloride, phosphorus, ammonia, kjeldahl nitrogen, sodium, cadmium, mercury, selenium, and chromium as low load constituents in urban runoff.
- Estimated annual runoff loads of suspended solids, BOD_5, copper, zinc, chromium, nickel, and iron from the Second Creek basin to Fort Loudoun Reservoir were found to exceed the loads from area wastewater treatment plants that discharge to the reservoir. This finding may have significant implications regarding the relative impact of urban runoff and wastewater treatment plant discharges to receiving waters, such as Fort Loudoun Reservoir. Additional information would be needed, however, to better define this relationship.
- Copper, chromium, and cadmium were the metals that were found to have the highest percentage of their concentration in the soluble phase. Zinc and manganese were moderately soluble, while aluminum, lead, and iron were found mostly in the particulate phase in the urban runoff from all basins sampled.

- Bacteriological measurements indicated the presence of fecal coliforms far in excess of EPA's fecal coliform criteria for bathing waters. Fecal coliform to fecal streptococcus ratios indicate that bacterial contamination in the study area is most likely of animal waste origin.
- Specific identification of bacteria in the urban runoff indicated, with a high degree of certainty, the presence of Salmonella enteritides at all study sites.
- The distribution of bacterial load (number of organisms) was found to be evenly proportioned throughout runoff events, implying an absence of the "first flush" effect commonly associated with other pollutants in urban runoff.
- Fluoranthane was the only organic priority pollutant detected in the urban runoff during the study.
- Wetfall contributions were found to greatly exceed dryfall inputs for all constituents with the exception of aluminum and chloride, which were nearly always greater in the dry precipitation.

2. Effect of carbonate-rock geology on urban runoff quantity in the Second Creek Basin

   - In the upper and lower sink basins only approximately 20 percent of the expected normal annual runoff occurred during the study period with the greatest losses occurring during months with lower flows.

- Based on model simulations for two water years, in the upper and lower sink areas, losses of potential runoff into carbonate-rock solution cavities can be several times larger than the volume of surface flow which is observed.
- Modeling results for the four water quality sites (CBD, SC, R1, and R2) indicate that most of the potential runoff originating from pervious areas within these watersheds drain into the carbonate rock solution system.
- Transmission runoff losses will tend to decrease as impervious area percentage increases.
- Runoff coefficients generally will be related to percent impervious area but can be quite variable depending on the extent of soluble carbonate rock in a basin.
- Urban runoff into sinkholes may contaminate aquifers in Karst areas thus resulting in contamination of groundwater wells.

The hydrological data collected during this study and the model simulations performed utilizing that data have shown with a reasonable degree of certainty that the soluble carbonate rock in the Second Creek basin is a dominating factor relative to the urban hydrology of the area. Inasmuch as the present study's area is affected, a significant quantity of the potential runoff does not leave the study basin via surface runoff but drains through soluble carbonate-rock cavities probably emerging in springs within the same watershed although a detailed study conducted in the upper portion of Second Creek Watershed indicated that some of the drainage is possibly transferred into the First Creek drainage basin.

3. The effect of carbonate geology on urban runoff quality. Having shown how the soluble carbonate-rock dominates the urban hydrology in the Second Creek basin, it would seem reasonable to conclude that chemical constituents associated with the urban hydrology would be similarly affected. This may not necessarily be the case because physical/chemical properties of the soil overburden can act as a chemical sink for urban runoff pollutants, thus reducing their presence in either the surface runoff or the groundwater. However, equilibrium conditions in the soil overburden may become manifested and the displacement of some chemical species could occur while other less reactive species could infiltrate to the carbonate solution channels without change, and a percentage of all constituents could enter the groundwater directly through surface connected solution channels.

Considering the above concepts, the following conclusions are presented concerning the potential loss of pollutants in urban runoff to the groundwater system in the Second Creek basin.

- The ratio of atmospheric mass input to surface mass output is larger for the study basins with smaller percent impervious areas (R1 and R2), and smallest for basins with higher percent impervious areas (SC and CBD).
- A positive relationship was found between the input/output ratios of less reactive pollutants and antecedent dry days.

- The loss of pollutants in urban runoff to the groundwater system is seasonal, with greater quantities lost during dry months and the least during the wet.

In general, the preponderance of indirect evidence indicates that both urban runoff hydrology and pollutants in urban runoff may be profoundly influenced in drainages which are underlain by soluble carbonate rock. The impact of urban runoff on the quality of ambient groundwater, however, cannot be determined with the data in this study. Direct measurements of groundwater quality would be needed to determine this.

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APPENDIXES

APPENDIX A

STATISTICAL COMPARISON OF TVA AND AEROCHEM METRICS WET-DRY COLLECTORS

Appendix A

Statistical Analysis of TVA Versus Aerochem Metrics Model 201 Wet Deposition Monitoring Data

Correlation Coefficients Between Collectors by Parameter

Parameter	R	Significance
Volume	0.02	0.91
Field pH	0.56	<0.01
Lab pH	0.55	<0.01
Weak Acid	0.81	<0.01
Strong Acid	0.50	0.01
Conductance	0.57	<0.01
$SO_4^=$	0.74	<0.01
NO_3^-	0.31	0.09
$PO_4^\equiv$	0.75	<0.01
F^-	0.35	0.05
Cl^-	0.32	0.09
NH_4^+	0.84	<0.01
K^+	0.59	<0.01
Na^+	0.27	0.15
Ca^{++}	0.26	0.15
Mg^{++}	0.17	0.43

APPENDIX B

QUALITY ASSURANCE PROGRAM

QUALITY ASSURANCE PROGRAM FOR SECOND CREEK NURP PROJECT

1.0 OJBECTIVE

The objectives of this quality assurance program was to assure that valid and reliable data were reported and to assess the accuracy and precision of the data generated so that accurate interpretations could be made.

2.0 SCOPE

The program covered the activities that affect the quality of the analytical data generated on the Second Creek NURP project. The various functions covered include cleaning and calibration of sampling equipment, field measurements, sample handling and preservation, laboratory quality control, and data handling.

3.0 REFERENCES

3.1 *Data Collection Quality Assurance for the Nationwide Urban Runoff Program*, Water Planning Division, U.S. Environmental Protection Agency, Washington, D.C.

3.2 *Workplan Guideline for Nationwide Urban Runoff Program*, Water Planning Division, U.S. Environmental Protection Agency, Washington, D.C.

3.3 "Standard Methods for Routine Water Quality and Aquatic Biological Field Surveys," WQEB-SS-1, Water Resources Operations, Division of Water Resources, Tennessee Valley Authority, June 1978.

3.4 "Stream-Gaging Procedure," Water Supply Paper 888, United States Government Printing Office, Washington, D.C. (1943).

3.5 "Water Measurement Manual," second edition, United States Department of Interior, Denver, Colorado (1967).

3.6 "Preparation of Sample Containers," NRS-LB-AS-3.1, Laboratory Branch, Division of Natural Resource Services, Tennessee Valley Authority, April 1980.

3.7 "Guidelines Establishing Test Procedures for Analysis of Pollutants: Proposed Regulations," Federal Register, 44(233), Part III, 69464-575 (December 3, 1979).

3.8 "Receiving and Logging Samples," NRS-LB-AS-3.5, Laboratory Branch, Division of Natural Resource Services, Tennessee Valley Authority, March 1980.

3.9 "Performing Interlaboratory Quality Control," NRS-LB-QAP-3.5, Laboratory Branch, Division of Natural Resource Services, Tennessee Valley Authority, February 1980.

3.10 "Preparing Worksheets and Forms," NRS-LB-AS-3.6, Laboratory Branch, Division of Natural Resource Services, Tennessee Valley Authority, March 1980.

3.11 "Performing Routine Analysis," NRSLB-QAP-3.1, Laboratory Branch, Division of Natural Resource Services, Tennessee Valley Authority, March 1980.

3.12 "Methods of Chemical Analysis of Water and Wastes," Environmental Protection Agency, Cincinnati, Ohio (1979).

3.13 Guy, H. P., "Laboratory Theory and Methods for Sediment Analysis," Book 5, Chapter C1, in Techniques of Water-Resources Investigations of the United States Geological Survey, U.S. Government Printing Office, Washington, D.C. (1969).

3.14 Operation and Maintenance Manual for Dionex Auto Ion System 12 Analyzer, Dionex Corporation, Sunnyvale, California (1979).

3.15 "Performing Intralaboratory Quality Control Analyses," NRS-LB-AS-3.9, Laboratory Branch, Division of Natural Resource Services, Tennessee Valley Authority, May 1980.

3.16 "Recording, Checking, and Approving Analytical Data," NRS-LB-AS-3.10, Laboratory Branch, Division of Natural Resource Services, Tennessee Valley Authority, June 1980.

3.17 "Preparing Reports of Results," NRS-LB-AS-3.12, Laboratory Branch, Division of Natural Resource Services, Tennessee Valley Authority, June 1980.

3.18 "Retaining and Storing Quality Assurance Records," NRS-LB-QAP-6.6, Laboratory Branch, Division of Natural Resource Services, Tennessee Valley Authority, January 1980.

3.19 "Retaining and Storing Quality Related Records," NRS-LB-AS-6.1, Laboratory Branch, Division of Natural Resource Services, Tennessee Valley Authority, February 1980.

3.20 "Performing Intralaboratory Quality Control Analyses," NRS-LB-AS-3.9, Laboratory Branch, Division of Natural Resource Services, Tennessee Valley Authority, May 1980.

3.21 Methods for Determination of Inorganic Substances in Water and Fluvial Sediments, p. 57, U.S. Geological Survey, Book 5, Chapter A1, Denver, Colorado (1979).

3.22 "Nationwide Urban Runoff Program (NURP) Second Creek Project Execution Plan," Water Quality Branch, Division of Water Resources, Tennessee Valley Authority, April 1981.

4.0 ABBREVIATIONS AND DEFINITIONS

4.1 LB--Tennessee Valley Authority's Laboratory Branch

4.2 QAC--Quality Assurance Coordinator of Laboratory Branch

4.3 PM--Project Manager

4.4 AO--Administrative Officer of Laboratory Branch

4.5 STORET--A water quality control information system maintained by the Environmental Protection Agency.

5.0 PROCEDURES AND RESPONSIBILITIES

5.1 Sample Collection, Shipping, and Receiving (A flow chart showing these steps is given in Attachment 1.)

5.1.1 Automatic Sampling equipment was cleaned by the procedure described on pages 36-39 of reference 3.1. Equipment used in the collection of grab samples was cleaned as described in reference 3.3.

5.1.2 A maintenance program which involved periodic inspection, servicing, and calibration of project equipment was established for all monitoring equipment. Written documentation of initial calibration and all further calibration was prepared.

5.1.2.1 Periodic calibrations on all data and sample gathering equipment were made at least on a monthly basis and, if deemed necessary, on a weekly basis throughout the collection period. Maintenance was performed during regular servicing trips.

5.1.2.2 Automatic sampling equipment, water level and precipitation recorders, and wet/dry fallout collectors were checked during every servicing trip.

5.1.2.3 Raingages were calibrated using references 3.4 and 3.5 prior to installation and at least every six months during the project life.

5.1.2.4 For flow measuring devices (flumes) the manufacturer's calibration or rating was used and verified by periodic flow measurements using current meters over the range of flows expected.

5.1.2.5 At sites requiring current meter measurements to establish flow-stage relationships, the ratings developed were checked by periodic measurements throughout the life of the project to define any shifts in the rating.

5.1.3 Sample containers were cleaned, predosed with preservatives, labeled, and each batch of containers checked by randomly selecting several sample containers for quality control analyses (reference 3.6). These containers were filled with deionized water and the blank sample analyzed for the required parameters.

5.1.4 Temperature, pH, dissolved oxygen, and specific conductance were measured in the field through the use of a Hydrolab Surveyor. The procedure for the calibration and operation of this *in situ* instrument can be found on pages II-1 through 8 of reference 3.3.

5.1.5 Samples were collected and preserved as described on pages 20-23 of reference 3.1. All samples were identified using a unique numbering system.

5.1.6 In addition to the sample collection specified in the Second Creek Execution Plan (reference 3.22), approximately 20 percent of all samples were collected in duplicate for quality control purposes.

5.1.7 A field blank was collected for organic priority pollutants and shipped to the LB as described on page 69554 of reference 3.7.

5.1.8 Samples were received by the LB and all necessary information regarding the samples recorded in accordance with instructions recorded in reference 3.8.

5.1.9 The QAC checked all samples and records for any irregularities.

5.1.9.1 The QAC notified the PM of any irregularity regarding the samples.

5.1.9.2 The PM resolved all problems or questions before the samples were released for analysis.

5.1.10 The QAC prepared blind laboratory duplicates by combining half of the duplicate pairs of samples collected and redispensing the combined samples back into clean sample containers. This eliminated any field and collection variability in the blind laboratory duplicates. The remainder of the duplicate pairs of samples collected were submitted blind to the LB to assess field plus laboratory variability. The QAC also submitted on a regular basis blind reference samples in accordance with reference 3.9.

5.1.11 The QAC prepared laboratory worksheets (reference 3.10) and submitted the samples and worksheets to their proper locations.

5.2 Laboratory Analysis and Data Reporting (A flow chart showing these steps is given in Attachment 2.)

5.2.1 Samples and blanks were analyzed (reference 3.11) for the parameters listed in Attachment 3. The references, type of analysis, and detection limits of the analytical procedures are also listed in Attachment 3.

5.2.2 The LB Intralaboratory Quality Control Program (reference 3.20) was following by analyzing 10 percent of the samples in duplicate and, when possible, spiking 10 percent of the samples.

5.2.3 The results from the accuracy and precision quality control samples were plotted on control charts.

5.2.3.1 If a result was outside the control limits, the samples were resubmitted for analysis.

5.2.4 All analytical data was recorded in laboratory notebooks (reference 3.16), calculations checked, analysis approved, and results forwarded to the QAC.

5.2.5 The QAC summarized the blind laboratory and field duplicates along with the blind reference samples.

5.2.6 If the data indicated a problem the QAC took corrective actions. If possible the samples were resubmitted for analysis.

5.2.7 The QAC compared the blind laboratory duplicates with the field duplicates.

5.2.8 If there was a significant difference between the laboratory and field variability, the QAC notified the PM of homogenity problems.

5.2.9 The QAC "flagged" all questionable data.

5.2.10 The QAC forwarded the data to the PM, who prepared the report of results and forwarded the results to data processing (reference 3.17).

5.2.11 The data was keypunched, verified, and stored in the STORET data system.

5.2.12 Completed printouts of data were forwarded to the PM and QAC.

5.2.13 The PM and QAC reviewed the printout for reasonableness and approved final printout of data.

6.0 QUALITY CONTROL METHODS

6.1 Blanks

6.1.1 Blank samples were analyzed to determine whether sample containers contributed any of the parameters to be measured during prolonged storage. The 5-gallon plastic carboys used for the collection of the composite samples were thoroughly cleaned, then filled with deionized water. Deionized water was allowed to remain in contact with the carboy for approximately 24 hours. The deionized water was then placed into the sample "churn splitter" (the routine procedure for assuring homogenity of composite samples) and the sample split into the required predosed sample bottles.

6.1.2 Precipitation blanks were prepared by placing 500 ml of deionized water into a thoroughly cleaned plastic collection bucket. The sample was allowed to contact the plastic container for 24-hours. The sample was then prepared and analyzed in the same manner as other precipitation samples.

6.2 Control Charts

6.2.1 Evaluation of Accuracy

6.2.1.1 Data for accuracy quality control charts were generated by analyzing actual samples spiked with known amounts of the analyte. The percent recovery was determined, and 100 percent was subtracted from the recovery to obtain the percent bias. This value was plotted on control charts indicating upper and lower warning and control limits.

6.2.1.2 Limits for accuracy control charts were calculated from actual recovery data obtained from analysis of large batches of samples (nominally, at least 20 percent bias values). From the individual percent bias values, the mean ($\bar{x}$) and the standard deviation (SD) were calculated. Warning limits (UWL and LWL) and control limits (UCL and LCL) were obtained as $\bar{x} \pm 1$ SB and $\bar{x} \pm 2$ SD, respectively.

6.2.1.3 Two consecutive points or repeated points outside the warning limits required a close examination of the system to prevent it from going out of control. The analysis was judged "out of control" when any point fell outside the control limits. Standard policy was to reanalyze all samples determined during a period shown to be out-of-control.

6.2.2 Evaluation of Precision

6.2.2.1 Data for precision quality control charts were generated by analyzing actual samples in duplicate. The difference between the two values was multiplied by 0.89 to obtain the standard deviation (SD). The standard deviation times 100 divided by the mean of the duplicate values yielded the relative standard deviation in percent (percent RSD). The percent RSD was used in plotting precision control charts.

6.2.2.2 Limits for precision control charts were calculated from actual precision data from large batches of samples (nominally, at least 20 percent RSD values). From the individual values of relative standard deviation, the mean ($\bar{x}$) and standard deviation (SD) were calculated. The upper warning and control limits (UWL and UCL) were $\bar{x}$ + 1 SD and $\bar{x}$ + 2 SD, respectively.

6.2.2.3 Two consecutive points or repeated points outside the warning limit required corrective action. The analysis was judged out-of-control when any point fell outside the control limits. Standard policy was to reanalyze all samples determined during a period shown to be out-of-control.

6.3 Reference Samples

6.3.1 Standard aqueous reference samples (SRM) supplied by Environmental Resource Associates (ERA) and Environmental Protection Agency (EPA) having a certified concentration of the parameters analyzed on the Second Creek samples were analyzed as blind samples on a frequency of approximately bimonthly. These results were used to provide a measure of the accuracy of the overall data set.

6.3.2 The recovery data for each parameter was summarized by calculating the mean percent recovery and standard deviation (SD). An estimate of the reliability of this mean recovery value was calculated using the equation $\bar{x} \pm \frac{t\ SD}{n}$ where t is the students t value and n the number of reference samples determined. This interval means that there is a 95 percent chance the true percent recovery value lies within the values. If there is no statistically significant bias in the analytical procedure, the 95 percent confidence interval of the mean should encompass 100 percent recovery.

6.4 Blind Split Samples

6.4.1 Blind Field Duplicates

6.4.1.1 Duplicate samples were periodically collected through the use of a second automatic sampler which was installed at one of the four sampling sites.

6.4.1.2 When the samples were received by the LB, the QAC assigned new numbers to all the samples in the batch and the samples were inserted into the analytical stream.

6.4.1.3 The relative standard deviation was calculated from these duplicate data as described in section 6.1.2.1.

6.4.2 Laboratory Duplicates

6.4.2.1 The QAC of the LB prepared a second aliquot from the original sample through the use of a sample splitter. New numbers were assigned to all the samples in the batch and the samples inserted into the analytical stream.

6.4.2.2 The relative standard deviation was calculated from these duplicate data as described in section 6.1.2.1.

7.0 RESULTS AND DISCUSSION

7.1 Blank Samples

7.1.1 Blank solutions for both composite as well as precipitation samples were prepared as described in section 6.1. The results of these analysis are described in Attachment 4.

7.1.2 From the data, it appears that both the 5-gallon plastic carboy (used for the composite samples) and the plastic collection bucket (used for precipitation samples) contain a leachable organic material. Even after thorough cleaning, after deionized water was allowed to contact for 24 hours, significant concentrations of TOC and COD were obtained. Although the concentrations of leachable metals (Ca, Mg, Na, K, Cu, Zn) were low, values for these parameters are significant when compared to the low concentrations obtained in precipitation samples.

7.1.3 Field blanks for priority pollutant analysis were analyzed with both sample collections. All results (except for a concentration of 14 µg/L for 1,1,1 Trichloroethane on one sample) were less than the detection limits. Although methylene chloride was not detected in the blank for the October 1981 collection, the samples had obviously been contaminated because the container used for compositing had not been properly prepared. Any value obtained for methylene chloride should, therefore, be considered as questionable.

7.2 Control Charts

7.2.1 Intralaboratory control charts for all parameters analyzed (with the exception of organic priority pollutants) on the Second Creek project were maintained as described in section 6.2. During this period when the samples for the Second Creek project were collected, most duplicate and spiked samples were within the "control limits" or when "out-of-control" situations occurred, all the samples within that batch were reanalyzed.

7.3 Reference Samples

7.3.1 Blind reference samples were inserted into the analytical stream as described in section 6.3. These samples were periodically analyzed to assess the accuracy of the analytical measurements. The results of these analyses are tabulated in Attachment 5.

7.3.2 Only sulfate, pH, and total Kjeldahl nitrogen parameters displayed a significant bias. This bias is exhibited by the 95 percent confidence interval of the mean recovery not encompassing 100 percent recovery for these parameters. These situations were interpreted to mean that there was a significant difference (at the 95 percent level of significance) between the mean recovery obtained and 100 percent recovery or zero percent bias.

7.3.3 Although the 95 percent confidence interval of the mean recovery for sulfate did not encompass 100 percent recovery, the bias was only 2.6 percent and should not affect the overall interpretation of the data.

7.3.4 Low pH values are obtained on samples having low ionic strength because of a phenomenon known as "streaming potential." Since the reference samples generally have a low ionic strength, this could account for the -6.3 percent bias obtained on these samples. Negative bias would not be encountered on the composite samples since they have a significant concentration of dissolved ions. However, pH measurements on the precipitation samples were affected. Laboratory studies performed since the completion of the

Second Creek project have shown that if steps are not taken to prevent the streaming potential effect, the pH values on precipitation samples are approximately 0.1 to 0.3 pH units low.

7.3.5 Mean recovery for the seven reference samples submitted for total Kjeldahl nitrogen was 89.4 percent. This negative bias was exhibited because the EPA reference samples contained organic nitrogen compounds which were not completely digested by the analytical procedure utilized by the laboratory. Because of this, the organic nitrogen data on the Second Creek samples should be considered as recoverable organic nitrogen. Observed organic nitrogen values may be slightly less than the actual concentration present in the samples. This is consistent with EPA's definition of total Kjeldahl nitrogen which defines the parameter as the sum of the free-ammonia and organic nitrogen compounds which are converted to ammonium sulfate under the conditions of the digestion described in the procedure.

7.3.6 Blind reference samples for the organic priority pollutants were inserted into the analytical stream with both sample collections for priority pollutants as described in section 6.3. Recoveries for the individual compounds are shown in Attachment 6. A summary of the results by the compound classification is shown in Attachment 7. Although the recoveries for the individual compounds varied greatly, the 95 percent confidence interval for the overall mean recovery for three of the four classes of compounds encompassed 100 percent recovery. The acid extractable compounds averaged only 62 percent recovery. These low recoveries for the acid extractable compounds are expected since results obtained by other laboratories also show low recoveries.

7.4 Laboratory Duplicates

7.4.1 Blind laboratory duplicates were prepared and inserted into the analytical stream as directed in section 6.4.2. Results on these duplicate samples are summarized in Attachment 8.

7.4.2 The mean relative standard deviation (MRSD) calculated from the data from the duplicate samples for each parameter ranged from a low of 1.6 percent for conductance to a high of 42.6 percent for dissolved cadmium. The MRSD for all measurements was 11 percent. The wide range of results for the percent RSD was not only because of the differences in the reproducibility of each analytical methodology, but also because of the concentration of the parameters measured. An example of this was dissolved copper where a percent RSD of 30.6 was obtained. However, the mean concentration of the duplicates measured was only 17 μg/L. This substantiates the fact that the lower the concentration, the less precise the measurement, thus resulting in a high percent RSD. This can also account for the high percent RSD for other determinations such as dissolved iron, manganese, zinc, cadmium, lead and aluminum, total copper and chromium, and ammonia nitrogen.

7.4.2 The following parameters (excluding above-mentioned parameters) gave percent RSD values greater than 10--nonfiltrable residue, fecal coliform, fecal streptococcus, total and dissolved Kjeldahl nitrogen, dissolved phosphorus, total and dissolved organic carbon. Variability in the data for these parameters is caused not only by the variability within the analytical procedure, but also by biological activity which affects the results on each of the above parameters.

7.5 Field Duplicates

7.5.1 Blind field duplicates were collected, prepared, and inserted into the analytical stream as directed in section 6.4.1. Results on these field duplicates are summarized in Attachment 8.

7.5.2 The mean relative standard deviation calculated from paired data for each parameter ranged from a low of 0.9 percent for chloride to a high of 44.9 percent for dissolved copper. The mean relative standard deviations for all measurements was 15 percent. This value compared to an overall mean of 11 percent for the mean of the laboratory duplicates indicates that most of the variability within the data is due to the analytical procedure.

7.5.3 Since there was a limited number of field duplicates collected, only limited interpretation can be applied to individual parameters. Four parameters which showed significant differences between the laboratory and field duplicates were fecal coliform, fecal streptococci and 5-day BOD. The mean percent RSD for the field duplicates ranged from 21.2 percent for BOD 5-day to 43.8 percent for fecal coliform.

8.0 CONCLUSIONS

8.1 The overall accuracy and precision of data generated during the Second Creek project was adequate and within the interpretative requirements of the study. The quality control program did, however, reveal certain limitations which must be considered when interpreting the results of some parameters.

8.2 Based on a limited number of samples, it appears that deionized water leached a significant concentration of organic material from the plastic carboys. The TOC and COD values for the composite samples, especially those having a low concentration, should be used with caution.

8.3 Detectable concentrations of metals (Ca, Mg, Na, K, Cu, and Zn) were leached from the plastic buckets used to collect the precipitation samples, and these data should be used with caution.

8.4 The pH values for precipitation samples are approximately 0.3 pH unit low because of the low ionic strength of the samples. Therefore, actual values could be as much as 0.3 units higher than the reported values.

8.5 Organic nitrogen values should be considered as recoverable and may be slightly less than the actual concentration present.

8.6 Because of the low metal concentrations in most of the samples, the metals determinations (iron and dissolved species of manganese, zinc, cadmium, lead, aluminum and total copper and chromium) showed a high variability within the data and should be considered when interpreting the data.

8.7 Because of the nature of the determination and the type samples analyzed, the following parameters were less precise than the other determinations. The parameters that gave percent RSD values greater than 10 were TSS, nonfiltrable residue, fecal coliform, fecal streptococcus, total and dissolved Kjeldahl nitrogen, dissolved phosphorus and total and dissolved organic nitrogen. The percent RSD should be considered for each parameter when interpreting the data.

8.8 Results from the field duplicates indicated a high variability in the collection of samples for fecal coliform, fecal streptococcus and 5-day BOD and, therefore, the data on these parameters should be used with caution.

8.9 Since some sample containers used for collecting organic priority pollutants were not properly cleaned, any value obtained for methylene chloride should be considered as questionable.

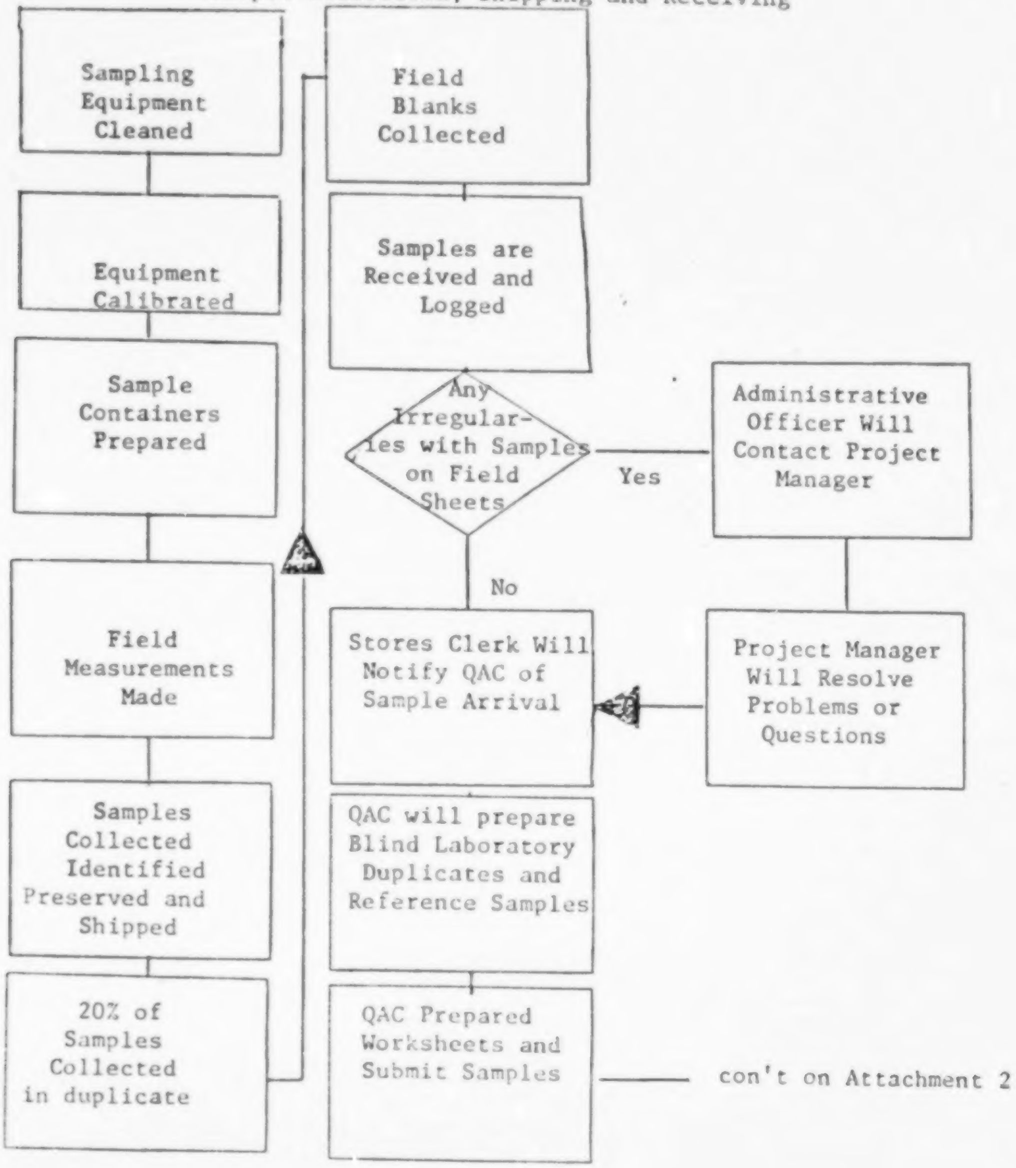
8.10 Low recoveries were obtained for the organic priority pollutant compounds on reference samples. However, low recoveries are expected since results obtained by other laboratories also show low recoveries. These low recoveries should be considered when interpreting the organic priority pollutant data.

ATTACHMENTS

1. Flow chart for sample collection, shipping, and receiving.
2. Flow chart for laboratory analysis and data reporting.
3. Analytical methodology.
4. Results of blank samples.
5. Results of blind reference samples.
6. Results of organic priority pollutant reference samples.
7. Summary of results of organic priority pollutants by classification of compound.
8. Results of blind duplicates.

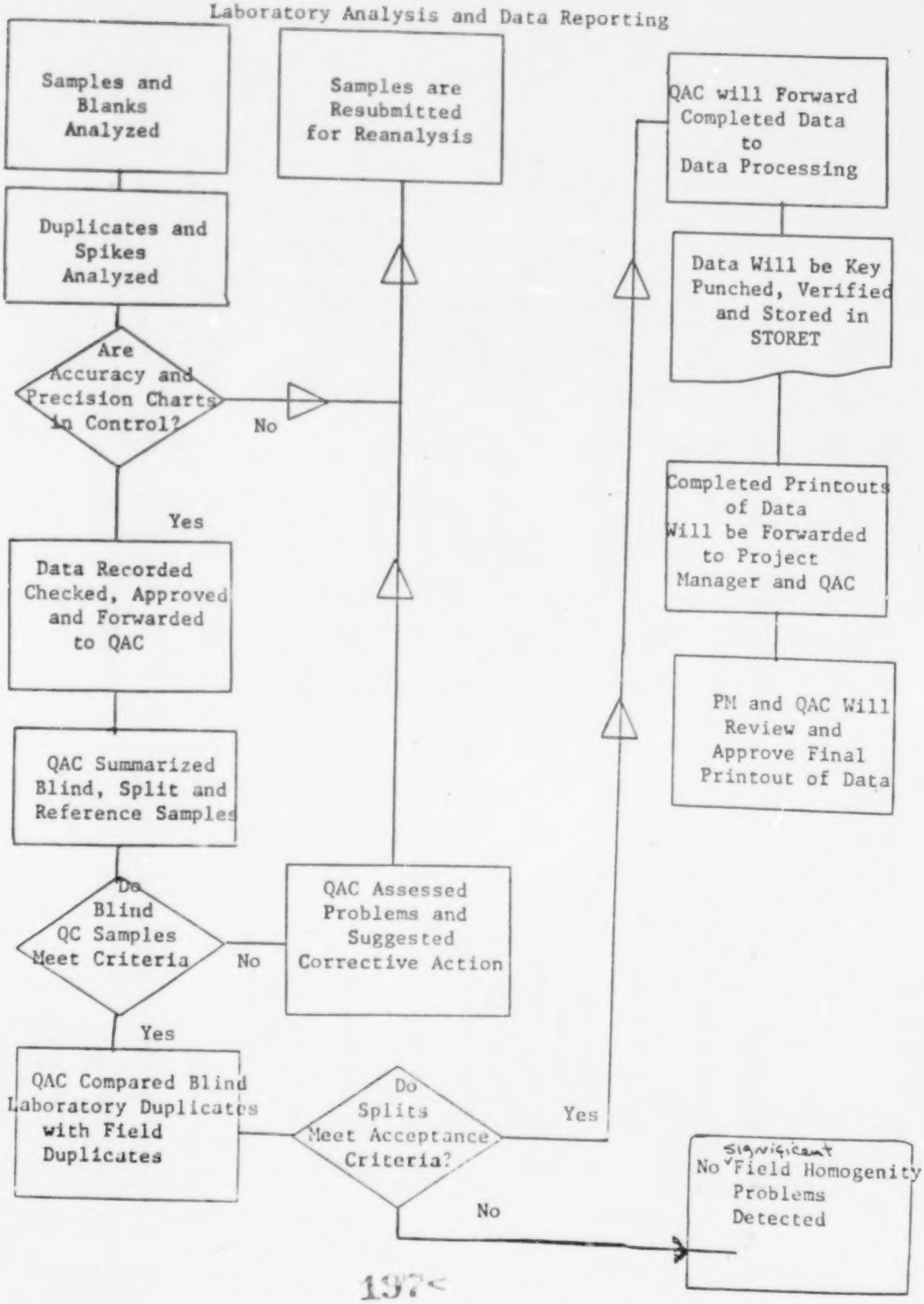
Attachment 1

Sample Collection, Shipping and Receiving


Sampling Equipment Cleaned
Equipment Calibrated
Sample Containers Prepared
Field Measurements Made
Samples Collected Identified Preserved and Shipped
20% of Samples Collected in duplicate
Field Blanks Collected
Samples are Received and Logged
Any Irregularies with Samples on Field Sheets
Yes
No
Administrative Officer Will Contact Project Manager
Project Manager Will Resolve Problems or Questions
Stores Clerk Will Notify QAC of Sample Arrival
QAC will prepare Blind Laboratory Duplicates and Reference Samples
QAC Prepared Worksheets and Submit Samples
con't on Attachment 2

Attachment 2

Laboratory Analysis and Data Reporting


Samples and Blanks Analyzed
Duplicates and Spikes Analyzed
Are Accuracy and Precision Charts in Control?
No
Yes
Data Recorded Checked, Approved and Forwarded to QAC
QAC Summarized Blind, Split and Reference Samples
Do Blind QC Samples Meet Criteria
No
Yes
QAC Compared Blind Laboratory Duplicates with Field Duplicates
Samples are Resubmitted for Reanalysis
QAC Assessed Problems and Suggested Corrective Action
Do Splits Meet Acceptance Criteria?
Yes
No
QAC will Forward Completed Data to Data Processing
Data Will be Key Punched, Verified and Stored in STORET
Completed Printouts of Data Will be Forwarded to Project Manager and QAC
PM and QAC Will Review and Approve Final Printout of Data
No significant Field Homogenity Problems Detected

Attachment 3

Analytical Methodology

Parameter	Reference	Method Description	Minimum detectable amount
Residue, nonfiltrable	3.12, Method 160.2	Gravimetric	1 mg/L
Residue, filtrable	3.12, Method 160.1	Gravimetric	10 mg/L
Particle size analysis	3.13, Pages 23-26	Gravimetric	-
Specific conductance	3.12, Method 120.1	Wheatstone bridge	0.1 µmho/cm
pH	3.12, Method 150.1	Electrometric	-
Nitrate plus nitrite nitrogen	3.12, Method 353.2	Colorimetric, automated cadmium reduction	0.01 mg/L
Ammonia nitrogen	3.12, Method 350.1	Colorimetric, automated phenate	0.01 mg/L
Kjeldahl nitrogen (total and dissolved)	3.12, Method 351.1 (with LB Modifications)	Colorimetric, automated phenate	0.02 mg/L
Phosphorus (total and dissolved)	3.12, Method 365.1 (with LB Modifications)	Colorimetric, automated ascorbic acid	0.01 mg/L
Chloride	3.12, Method 325.1	Colorimetric, automated ferricyanide, AAI	1 mg/L
Sulfate	3.12, Method 375.4	Turbidimetric	1 mg/L
Orthophosphate	3.12, Method 365.1	Colorimetric, automated ascorbic acid	0.01 mg/L
Chloride, sulfate, nitrate and phosphate on precipitation samples	3.14	Ion chromatography	Cl-0.1 mg/L PO_4-P 0.01 mg/L SO_4-0.1 mg/L NO_3-N-0.01 mg/L
Calcium	3.12, Method 215.1	Atomic absorption - direct aspiration	0.01 mg/L
Magnesium	3.12, Method 242.1	Atomic absorption - direct aspiration	0.01 mg/L
Sodium	3.12, Method 273.1	Atomic absorption - direct aspiration	0.01 mg/L
Potassium	3.12, Method 258.1	Atomic absorption - direct aspiration	0.01 mg/L

Attachment 3

(Continued)

Parameter	Reference	Method Description	Minimum detectable amount
Calcium, magnesium and sodium on precipitation samples	3.12, Method 3.7	Atomic Emission	0.01 mg/L
Iron	3.12, Method 236.1	Atomic absorption - direct aspiration	0.05 mg/L
Manganese	3.12, Method 243.1	Atomic absorption - direct aspiration	0.01 mg/L
Organic carbon (total and soluble)	3.12, Method 415.1	Oxidation - infrared	0.02 mg/L
Chemical oxygen demand	3.12, Method 410.2	Titrimetric	1 mg/L
Biochemical oxygen demand	(5-day and ultimate)	Membrane electrode	1 mg/L
Priority Pollutants			
Pesticides and PCBs	3.7, Method 608	Gas chromatography	-
Purgeables	3.7, Method 624	Gas chromatography/mass spectrometry	
Base/neutrals and acid extractable	3.7, Method 625	Gas chromatography/mass spectrometry	-
Phenol	3.12, Method 420.1	Manual, 4-AAP with distillation	2 µg/L
Cyanide	3.12, Method 335.2	Spectrophotometric	0.02 mg/L
Antimony	3.20	Atomic absorption - gaseous hydride	2 µg/L
Berryllium	3.12, Method 210.1	Atomic absorption - direct absorption	0.01 mg/L
Cadmium	3.12, Method 213.2	Atomic absorption - furnace	0.1 µg/L
Chromium	3.12, Method 218.2	Atomic absorption - furnace	1 µg/L
Copper	3.12, Method 220.1	Atomic absorption - direct aspiration	0.01 mg/L

Attachment 3

(Continued)

Parameter	Reference	Method Description	Minimum detectable amount
Priority Pollutants (continued)			
Nickel	3.12, Method 249.1	Atomic absorption - direct aspiration	0.01 mg/L
Thallium	3.12, Method 283.1	Atomic absorption - direct aspiration	0.05 mg/L
Lead	3.12, Method 239.2	Atomic absorption - furnace	1 μg/L
Mercury	3.12, Method 245.1	Cold vapor, manual	0.2 μg/L
Zinc	3.12, Method 289.1	Atomic absorption - direct aspiration	0.01 mg/L
Arsenic	3.12, Method 206.3	Atomic absorption - hydride	2 μg/L
Selenium	3.12, Method 270.3	Atomic absorption - hydride	1 μg/L
Silver	3.12, Method 272.1	Atomic absorption - direct aspiration	0.01 mg/L

Attachment 4

Results of Blank Samples

Parameter	Composite "Blank"		Precipitation "Blank"	
	Number of observations	Mean concentration	Number of observations	Mean concentration
pH	1	5.8	2	5.3
Specific conductance	-	-	3	2.0 μmho/cm
Total solids	-	-	4	1.3 mg/bucket
Filtrable residue	2	<10 mg/L	2	0.0 mg/bucket
Nonfiltrable residue	2	<1 mg/L	2	0.5 mg/bucket
NO_3+NO_2-N	2	<0.01 mg/L	6	0.03 mg/bucket
NH_3-N	2	0.01 mg/L	-	-
Total kjeldahl nitrogen	2	0.08 mg/L	6	0.04 mg/bucket
Total phosphorus	2	<0.01 mg/L	6	<0.005 mg/bucket
TOC	2	4.5 mg/L	3	0.8 mg/bucket
COD	2	2.0 mg/L	3	5.0 mg/bucket
Fecal coliform	2	<10.0 colonies/100 ml	-	-
Fecal strep	2	<10.0 colonies/100 ml	-	-
BOD (5-day)	2	<1.0 mg/L	-	-
Sulfate	2	<1.0 mg/L	5	0.1 mg/bucket
Chloride	2	<1.0 mg/L	5	0.06 mg/bucket
Calcium	2	0.08 mg/L	5	0.14 mg/bucket
Magnesium	2	0.008 mg/L	5	0.03 mg/bucket
Sodium	2	0.08 mg/L	4	0.07 mg/bucket
Potassium	2	0.02 mg/L	4	0.03 mg/bucket

Attachment 4

(Continued)

Parameter	Composite "Blank"		Precipitation "Blank"	
	Number of observations	Mean concentration	Number of observations	Mean concentration
Copper	2	<1.0 µg/L	5	6.0 µg/bucket
Zinc	2	<5.0 µg/L	5	2.0 µg/bucket
Chromium	2	<1.0 µg/L	5	<0.5 µg/bucket
Selenium	2	<1.0 µg/L	4	<0.5 µg/bucket
Mercury	2	<0.2 µg/L	5	<0.1 µg/bucket
Nickel	2	<50 mg/L	4	<25 µg/bucket
Cadmium	2	<0.1 µg/L	5	0.1 µg/bucket
Lead	2	3.0 µg/L	5	0.4 µg/bucket
Iron	1	<5.0 µg/L	5	9.0 µg/bucket
Manganese	2	<5.0 µg/L	5	<2.0 µg/bucket
Aluminum	-	-	1	<25 µg/bucket

Attachment 5

Results of Blind Reference Samples

Parameter	Number of observations	Reference concentration range	Average percent recovery	Standard deviation	95% Confidence interval of the mean % recovery
Total alkalinity	7	20-230 mg/L as $CaCO_3$	100	2.2	100 ± 2.0
Sulfate	8	7-220 mg/L	97.1	3.1	97.1 ± 2.6
pH	6	7.0-9.2	93.5	4.0	93.5 ± 4.2
Conductivity	7	98-2300 µmho/cm	103	10.2	103 ± 9.4
Filtrable residue	8	50-1300 mg/L	98.4	5.8	98.4 ± 4.8
Nonfiltrable residue	4	22-79 mg/L	110	61.2	110 ± 97.3
Total kjeldahl nitrogen	7	0.40-4.9 mg/L	89.4	11.3	89.4 ± 10.4
Ammonia nitrogen	7	0.19-7.5 mg/L	99.2	7.1	99.2 ± 7.1
Nitrate + nitrogen nitrite	7	0.31-6.9 mg/L	100	11.0	100 ± 10
Total phosphorus	8	0.14-5.7 mg/L	100	5.8	100 ± 4.8
TOC	7	6.1-41 mg/L	107	20.9	107 ± 19.2
COD	7	15-99 mg/L	100	4.1	100 ± 3.8
BOD	5	17-62 mg/L	103	17.2	103 ± 21.4
Chloride	6	18-325 mg/L	103	4.2	103 ± 4.4
Calcium	6	5.1-55 mg/L	105	15.1	105 ± 15.8
Magnesium	6	1.7-23 mg/L	108	18.4	108 ± 19.3
Sodium	5	7.5-279	97.5	11.3	97.5 ± 14.0
Potassium	5	2.0-172 mg/L	98.5	11.9	98.5 ± 14.8
Iron	5	77-430 µg/L	112	24.8	112 ± 30.8
Manganese	5	48-370 µg/L	98.7	1.6	98.7 ± 2.0

Attachment 5

(Continued)

Parameter	Number of observations	Reference concentration range	Average percent recovery	Standard deviation	95% Confidence interval of the mean % recovery
Copper	6	17-250 µg/L	100	8.5	100 ± 8.9
Zinc	4	27-450 µg/L	105	7.2	105 ± 11.4
Nickel	5	100-290 µg/L	105	10.9	105 ± 13.6
Cadmium	7	8.6-90 µg/L	103	5.4	103 ± 5.0
Lead	7	60-510 µg/L	105	6.2	105 ± 5.7
Chromium	7	8.8-315 µg/L	92.9	9.4	92.9 ± 9.8
Selenium	4	14-26 µg/L	88.5	7.7	88.5 ± 12.2
Mercury	5	0.8-8.0 µg/L	101	6.4	101 ± 8.0
Aluminum	3	310-570 µg/L	114	7.9	114 ± 19.6
Cyanide	1	39 µg/L	108	-	-
Silver	1	48 µg/L	83.3	-	-
Arsenic	1	80 µg/L	97.5	-	-
Oil and grease	1	39 µg/L	97.4	-	-
Phenol	1	49 µg/L	106	-	-

Attachment 6

Results of Organic Priority Pollutant Reference Samples

Parameter	Type Compound	Date Submitted	Concentration Range (μg/L)	Percent Recovery
Benzene	Purgeable	10/02/81	91.4	109
Bromoform	"	"	26.6	90
Chloroform	"	"	36.9	114
Dichlorobromomethane	"	"	72.3	101
1,2-Dichloroethene	"	"	15.9	132
Toluene	"	"	29.3	109
1,2-Trans-Dichloroethylene	"	"	23.2	116
Benzene	"	02/04/82	30.5	216
Bromoform	"	"	26.6	90
Chlorodibromomethane	"	"	18.9	90
Chloroform	"	"	73.7	88
1,2-Dichloroethane	"	"	47.8	199
2,4-Dimethylphenol	Acid Extractable	10/04/82	55.2	87
2,4-Dinitrophenol	"	"	99.6	310[a]
Phenol	"	"	88.6	34
2,4-Dimethylphenol	"	02/04/82	66.2	42
Phenol	"	"	47.3	44
2,4,6-Trichlorophenol	"	"	93.3	103
Bis(2-ethylhexyl)-phthalate	Base Neutral	10/04/82	24.3	103
4-Bromophenyl phenyl ether	"	"	40	102
3,3'-Dichlorobenzidine	"	"	60.5	124
Dimethyl phthalate	"	"	75.8	87
2,6-Dinitrotoluene	Base Neutral	10/04/82	48.8	125
Naphthalene	"	"	50	66
Pyrene	"	"	44.1	111
4-Chlorophenyl phenyl ether	"	02/04/82	56.2	605[a]
3,3'-Dichlorobenzidine	"	"	90.3	132
Di-N-Butyl Phthalate	"	"	28.8	101
Nitrobenzene	"	"	64	107
Pyrene	"	"	29.4	122
Alpha-BHC	Pesticide	10/02/81	0.50	100
4,4'-DDE	"	"	0.80	52
4,4'-DDD	"	"	0.40	80
Endrin	"	"	1.5	133
Heptachlor	"	"	0.20	50
Heptachlor Epoxide	"	"	0.50	100

a. Outliers are excluded from data summary.

Attachment 7

Summary of Results of Organic Priority Pollutants by Classification of Compound

Type compound	Number of observations	Concentration Range (µg/l)	Average percent recovery	Standard deviation	95% Confidence interval of the mean
Volatile	12	15.9-91.4	121	43	121 ± 27
Acid extractable	5	47.3-93.3	62	31	62 ± 38
Base neutral	11	24.3-90.3	107	19	107 ± 13
Pesticide	6	0.2-1.5	86	32	86 ± 34

Attachment 8

Results of Blind Duplicates

Parameter	Blind Laboratory Duplicates: Number of observations	Blind Laboratory Duplicates: Percent RSD	Blind Field Duplicates: Number of observations	Blind Field Duplicates: Percent RSD	Remarks
Sulfate	14	7.9	3	12.6	
pH	19	2.4	6	1.7	
Alkalinity	17	6.4	6	9.5	
Conductivity	18	1.6	5	4.7	
Filtrable residue	18	10.0	6	4.1	
Nonfiltrable residue	19	12.8	5	14.2	
Fecal coliform	15	21.7	5	43.8	
Fecal streptococci	13	12.7	5	21.7	
NO_3+NO_2-N	20	2.4	6	17.0	
NH_3-N	15	11.8	5	21.6	
Total Kjeldahl nitrogen	21	11.4	6	15.9	
Dissolved Kjeldahl nitrogen	18	20.0	5	16.7	
Total phosphorus	20	9.2	6	9.5	
Dissolved phosphorus	17	11.9	5	12.6	
Chloride	15	6.3	4	0.9	
Total organic carbon	16	17.2	6	16.5	
Soluble organic carbon	16	14.3	6	6.4	
COD	16	8.7	6	11.9	
BOD (5-day)	14	9.4	5	21.2	
Calcium	21	4.0	6	12.8	
Magnesium	21	4.6	6	9.0	
Sodium	16	7.4	4	9.0	
Potassium	16	5.7	4	4.6	

Attachment 8

(Continued)

Parameter	Blind Laboratory Duplicates: Number of observations	Blind Laboratory Duplicates: Percent RSD	Blind Field Duplicates: Number of observations	Blind Field Duplicates: Percent RSD	Remarks
Iron, total	21	13.9	6	2.0	
Iron, dissolved	9	26.7	3	28.1	
Manganese, total	19	5.2	6	15.1	
Manganese, dissolved	8	10.1	3	32.3	
Copper, total	20	27.9	5	35	
Copper, dissolved	10	30.6	3	44.9	
Zinc, total	20	6.2	5	8.7	
Zinc, dissolved	8	22.0	2	5.6	
Nickel, total	0	-	0	-	All values less than MDA[a]
Nickel, dissolved	0	-	0	-	All values less than MDA
Cadmium, total	21	7.9	6	17.9	
Cadmium, dissolved	7	42.6	4	20.1	
Lead, total	21	7.0	6	11.3	
Lead, dissolved	10	28.6	2	52.6	
Chromium, total	20	12.2	5	36	
Chromium, dissolved	6	2.1	2	0.0	
Selenium, total	0	-	0	-	All values less than MDA
Selenium, dissolved	0	-	0	-	All values less than MDA
Mercury, total	2	59.7	0	-	Only values greater than MDA
Mercury, dissolved	0	-	0	-	All values greater than MDA
Aluminum, total	10	9.6	2	9.5	
Aluminum, dissolved	2	55.6	0	-	

a. Minimum detectable amount

APPENDIX C

STORET CODES

Appendix C

STORET Code
for Knoxville, Tennessee
NURP Project

Sample Type	Parameter	STORET Code	Units
I. Dryfall	TKN	627	mg/kg
	TP	668	mg/kg
	NO_2,NO_3-N	633	mg/kg
	TOC	81951	mg/kg
	COD	339	mg/kg
	K	938	mg/kg
	Ca	917	mg/kg
	Mg	924	mg/kg
	Na	934	mg/kg
	SO_4	81612	mg/kg
	Cl	81376	mg/kg
	Fe, total	1170	mg/kg
	Mn, total	1053	mg/kg
	Cu, total	1043	mg/kg
	Zn, total	1093	mg/kg
	Cr, total	1029	mg/kg
	Se, total	1148	mg/kg
	Hg, total	71921	mg/kg
	Ni, total	1068	mg/kg
	Cd, total	1028	mg/kg
	Pb, total	1052	mg/kg
II. Wetfall	pH	403	Standard units
	Conductivity	95	μmhos at 25°C
	TDS	70300	mg/L
	TSS	530	mg/L
	TKN	625	mg/L as N
	TP	665	mg/L as P
	NO_2,NO_3-N	630	mg/L as N
	TOC	680	mg/L
	COD	335	mg/L
	K, total	937	mg/L
	Ca, total	916	mg/L
	Mg, total	927	mg/L
	Cl, total	940	mg/L
	Fe, total	1045	mg/L
	Mn, total	1055	μg/L
	Cu, total	1042	μg/L
	Zn, total	1092	μg/L
	Cr, total	1034	μg/L
	Se, total	1147	μg/L
	Hg, total	71900	μg/L

STORET Code
for Knoxville, Tennessee
NURP Project

(Continued)

Sample Type	Parameter	STORET Code	Units
II. Wetfall (continued)	Ni, total	1067	µg/L
	Cd, total	1027	µg/L
	Na, total	929	µg/L
	SO_4, total	945	mg/L
	Pb, total	1051	µg/L
III. Water Samples	pH	403	Standard units
	Conductivity	95	µmhos at 25°C
	TDS	70300	mg/L at 180°C
	TSS	530	mg/L
	NO_2,NO_3-N	630	mg/L
	NH_3-N	610	mg/L
	TKN	625	mg/L
	DKN	623	mg/L
	TP	665	mg/L
	DP	666	mg/L
	SOC	681	mg/L
	TOC	680	mg/L
	COD, low level	335	mg/L
	Fecal coliform	31616	MPN/100 ml
	Fecal strep	31679	MPN/100 ml
	Total alkalinity	410	mg/L as $CaCO_3$
	SO_4, total	945	mg/L
	Cl, total	940	mg/L
	Ca, total	916	mg/L
	Mg, total	927	mg/L
	Na, total	929	mg/L
	K, total	937	mg/L
	Cu, total	1042	µg/L
	Cu, dissolved	1040	µg/L
	Zn, total	1092	µg/L
	Zn, dissolved	1090	µg/L
	Cr, total	1034	µg/L
	Cr, dissolved	1030	µg/L
	Se, total	1147	µg/L
	Se, dissolved	1145	µg/L
	Hg, total	71900	µg/L
	Hg, dissolved	71890	µg/L

STORET Code
for Knoxville, Tennessee
NURP Project

(Continued)

Sample Type	Parameter	STORET Code	Units
III. Water Samples (continued)	Cd, total	1027	μg/L
	Cd, dissolved	1025	μg/L
	Pb, total	1051	μg/L
	Pb, dissolved	1049	μg/L
	Fe, total	1045	μg/L
	Fe, dissolved	1046	μg/L
	Mn, total	1055	μg/L
	Mn, dissolved	1056	μg/L
	Al, total	1105	μg/L
	Al, dissolved	1106	μg/L
	Ba, total	1007	μg/L
	Be, total	1012	μg/L
	As, total	1002	μg/L
	Mo, total	1062	μg/L
	Ti, total	1152	μg/L
	V, total	1087	μg/L
IV. Flow Data	Flow, total during composite period	50052	10^3 gallon
	Mean daily flow	60	cfs
	Instantaneous flow	61	cfs
	Stage	65	feet
V. Rainfall Data	Precipitation, duration of storm	117	minutes
	Precipitation/storm	82381	inches per storm
	Dry days preceding precipitation events	132	days
	Precipitation, cumulative at given time, Location 1	123	inches

STORET Code
for Knoxville, Tennessee
NURP Project

(Continued)

Sample Type	Parameter	STORET Code	Units
VI. BOD	BOD_1	303	mg/L at 20°C
	BOD_2	304	mg/L at 20°C
	BOD_3	305	mg/L at 20°C
	BOD_4	306	mg/L at 20°C
	BOD_5	310	mg/L at 20°C
	BOD_6	312	mg/L at 20°C
	BOD_7	315	mg/L at 20°C
	BOD_8	316	mg/L at 20°C
	BOD_9	317	mg/L at 20°C
	BOD_{10}	322	mg/L at 20°C
	BOD_{11}	327	mg/L at 20°C
	BOD_{12}	328	mg/L at 20°C
	BOD_{13}	329	mg/L at 20°C
	BOD_{14}	350	mg/L at 20°C
	BOD_{15}	323	mg/L at 20°C
	BOD_{16}	331	mg/L at 20°C
	BOD_{17}	332	mg/L at 20°C
	BOD_{18}	333	mg/L at 20°C
	BOD_{19}	334	mg/L at 20°C
	BOD_{20}	324	mg/L at 20°C
	BOD_{21}	351	mg/L at 20°C
	BOD_{22}	336	mg/L at 20°C

APPENDIX D

STORM EVENT SUMMARIES

Storm Event Summaries
Central Business District (CBD) Site

Beginning		Runoff duration (hrs)	Total volume (ft^3)			Average flow (cfs)	Rainfall duration (hrs)	Total rainfall (in)	Average intensity (in/hr)	Antecedent dry period (days)	Samples collected		
Date	Time		Runoff + Base	Base	Runoff						Water	Wetfall	Dryfall[a]
04-23-81	1324	6.00	7,338	1,080	6,258	0.34	7.00	0.61	0.09	2.50	No	No	No
05-14-81	1956	4.22	5,305	759	4,546	0.35	2.00	0.25	0.13	3.63	No	No	No
05-19-81	0024	10.53	18,767	1,896	16,871	0.50	7.17	0.60	0.08	0.71	No	No	No
05-19-81	1808	4.02	1,967	723	1,244	0.14	1.00	0.05	0.05	0.38	No	No	No
05-20-81	0847	14.65	12,975	2,637	10,338	0.25	9.00	0.25	0.03	0.25	No	No	No
05-25-81	1213	3.00	2,263	540	1,723	0.21	0.67	0.07	0.10	4.88	No	No	No
05-26-81	2053	b	b	b	b	b	15.00	1.41	0.09	1.08	No	No	No
05-30-81	1457	b	b	b	b	b	2.00	1.28	0.64	2.58	No	No	No
05-31-81	1944	3.20	7,358	576	6,782	0.64	1.50	0.23	0.15	0.96	No	No	No
06-02-81	0309	b	b	b	b	b	7.00	0.77	0.01	0.21	No	No	No
06-06-81	0349	b	b	b	b	b	7.00	2.19	0.31	1.33	No	No	No
06-06-81	1656	b	b	b	b	b	0.67	0.51	0.76	0.25	No	No	No
06-07-81	1542	1.58	2,077	285	1,792	0.37	0.67	0.06	0.09	0.88	No	No	No
06-10-81	1712	11.23	15,316	2,022	13,294	0.38	5.83	0.36	0.06	2.96	No	No	No
06-20-81	1829	2.20	4,449	396	4,053	0.56	0.50	0.18	0.36	8.54	No	No	No
06-22-81	2055	6.75	7,243	1,215	6,028	0.30	3.00	0.18	0.06	2.04	No	No	No
06-25-81	1624	7.60	12,423	1,368	11,055	0.45	2.00	0.40	0.20	2.67	No	No	No
07-01-81	2058	c	c	c	c	c	0.83	0.63	0.76	6.00	Yes	Yes	Yes
07-02-81	1625	1.73	1,608	283	1,325	0.28	0.33	0.02	0.06	0.54	No	No	No
07-06-81	1901	3.33	1,976	599	1,377	0.16	0.33	0.07	0.21	0.79	No	No	No
07-07-81	0322	3.95	8,316	711	7,605	0.58	1.33	0.22	0.17	0.29	No	No	No
07-10-81	1534	3.82	5,621	688	4,933	0.41	0.50	0.20	0.40	3.42	No	No	No
07-15-81	1626	4.68	1,787	842	945	0.11	1.00	0.07	0.07	4.96	No	No	No
07-16-81	0646	3.25	3,465	585	2,880	0.30	0.67	0.12	0.18	0.38	No	No	No
07-16-81	1500	4.63	3,393	834	2,559	0.20	2.50	0.10	0.04	0.29	No	No	No
07-20-81	1547	2.27	6,185	408	5,777	0.76	0.50	0.30	0.60	3.92	No	No	No
08-02-81	0557	7.80	9,974	1,404	8,570	0.36	b	b	b	b	No	No	No
08-06-81	0940	9.98	12,467	1,796	10,671	4.35	2.50	0.40	0.16	b	Yes	Yes	Yes
08-08-81	0047	3.05	6,512	549	5,963	0.59	2.00	0.22	0.11	1.13	Yes	No	No
08-15-81	1507	0.81	1,012	146	866	0.35	0.33	0.04	0.12	3.25	No	No	No
08-16-81	1007	2.30	4,364	414	3,950	0.53	0.33	0.21	0.64	0.25	Yes	Yes	Yes
08-18-81	1424	5.87	5,629	1,057	4,572	0.27	3.17	0.22	0.07	2.17	Yes	Yes	Yes
08-20-81	2151	10.43	35,076	1,877	33,199	0.93	8.00	1.23	0.15	2.08	Yes	Yes	Yes

a. Began monthly dryfall collection in November 1981.
b. Record lost due to equipment malfunction.
c. Flow indeterminable--above flume rating curve.

Storm Event Summaries
Central Business District (CBD) Site

(Continued)

Beginning		Runoff duration (hrs)	Total volume (ft^3)			Average flow (cfs)	Rainfall duration (hrs)	Total rainfall (in)	Average intensity (in/hr)	Antecedent dry period (days)	Samples collected		
Date	Time		Runoff + Base	Base	Runoff						Water	Wetfall	Dryfall[a]
09-01-81	1119	3.78	12,147	680	11,467	0.89	1.17	0.50	0.43	11.21	No	No	No
09-03-81	1507	9.58	17,333	1,724	15,609	0.50	3.00	0.82	0.27	2.08	No	No	No
09-14-81	2238	14.82	25,225	2,668	22,557	0.47	4.33	1.02	0.24	0.08	Yes	Yes	Yes
09-15-81	1737	10.05	17,531	1,809	15,722	0.48	5.67	0.78	0.14	0.25	No	Yes	Yes
10-01-81	2007	19.34	11,713	3,481	8,232	0.17	4.00	0.30	0.08	15.79	Yes	Yes	Yes
10-05-81	1155	6.80	11,662	1,224	10,438	0.48	1.83	0.37	0.20	3.46	No	No	No
10-18-81	0305	12.28	12,002	2,210	9,792	0.27	4.00	0.34	0.09	7.67	No	No	No
10-23-81	0235	13.32	38,057	2,398	35,659	0.79	8.83	0.96	0.11	4.63	Yes	Yes	Yes
10-25-81	0726	5.75	4,754	1,035	3,719	0.23	1.67	0.16	0.10	1.83	No	No	No
10-26-81	1900	13.00	31,502	2,350	29,162	0.67	4.83	0.76	0.16	0.25	Yes	Yes	Yes
11-19-81	2133	6.55	12,430	1,179	11,251	0.53	2.00	0.41	0.21	3.00	Yes	Yes	No
11-23-81	2022	9.43	14,995	1,697	13,298	0.44	5.16	0.46	0.09	4.33	Yes	Yes	No
12-01-81	0313	12.45	22,163	2,241	19,922	0.49	7.50	0.60	0.08	0.33	Yes	Yes	Yes
01-22-82	0535	31.13	34,783	3,393	31,390	0.31	10.0	0.90	0.09	0.88	Yes	Yes	No
02-02-82	1030	19.25	49,456	3,465	45,991	0.71	16.0	1.39	0.09	1.63	Yes	Yes	Yes
02-09-82	0344	15.92	32,805	2,866	29,939	0.57	9.00	0.97	0.11	2.83	Yes	Yes	No
03-04-82	2010	10.30	16,120	1,854	14,266	0.43	3.50	0.40	0.11	5.29	Yes	Yes	No
03-21-82	0449	9.18	29,867	1,652	28,215	0.90	7.50	0.87	0.12	1.79	Yes	Yes	No
03-25-82	1738	4.10	6,436	738	5,698	0.44	1.50	0.30	0.21	4.20	Yes	Yes	No
03-31-82	0617	4.13	10,391	743	9,648	0.70	3.33	0.35	0.11	5.33	Yes	Yes	No
03-31-82	1605	1.92	5,996	346	5,650	0.87	0.83	0.24	0.29	0.29	Yes	Yes	No
04-08-82	0710	9.72	11,721	1,750	9.971	0.34	4.67	0.45	0.10	7.54	Yes	Yes	No

a. Began monthly dryfall collection in November 1981.

Storm Event Summaries
Residential 1 (R1) Site

Beginning		Runoff duration (hrs)	Total volume (ft³)			Average flow (cfs)	Rainfall duration (hrs)	Total rainfall (in)	Average intensity (in/hr)	Antecedent dry period (days)	Samples collected		
Date	Time		Runoff + Base	Base	Runoff						Water	Wetfall	Dryfall[a]
04-17-81	0826	5.62	13,785	0	13,785	0.68	6.00	0.49	0.08	2.63	No	No	No
04-19-81	1858	13.85	16,867	0	16,867	0.34	8.50	0.62	0.07	1.13	No	No	No
05-10-81	1833	1.77	7,343	0	7,343	3.00	1.15	0.49	0.16	3.67	No	No	No
05-14-81	1958	1.70	8,831	0	8,831	1.44	0.83	0.35	0.42	3.58	No	No	No
05-19-81	0047	8.0	16,009	0	16,009	0.56	7.00	0.68	0.10	4.08	No	No	No
05-19-81	1817	1.28	2,613	0	2,613	0.57	1.67	0.15	0.09	0.42	No	No	No
05-20-81	1011	3.60	16,009	0	16,009	1.24	5.50	0.54	0.10	0.50	No	No	No
05-25-81	1334	1.65	3,310	0	3,310	0.56	2.67	0.36	0.13	4.92	No	No	No
05-27-81	1327	8.95	26,328	0	26,328	0.82	4.00	1.07	0.27	0.13	No	No	No
05-30-81	1415	4.42	24,669	0	24,669	1.55	2.00	0.94	0.47	2.63	No	No	No
06-02-81	0208	16.31	24,969	0	24,969	0.43	7.00	1.01	0.14	1.21	No	No	No
06-04-81	0718	2.85	33,522	0	33,522	3.27	5.33	1.15	0.22	1.42	No	No	No
06-04-81	1627	0.77	3,696	0	3,696	1.33	2.67	0.26	0.10	0.29	No	No	No
06-06-81	0627	15.0	89,256	0	89,256	1.65	7.00	2.75	0.39	1.38	No	No	No
06-20-81	1833	0.42	2,396	0	2,396	1.58	0.33	0.25	0.76	8.54	No	No	No
06-25-81	1813	0.88	2,713	0	2,713	0.86	3.00	0.38	0.13	2.17	No	No	No
07-01-81	2053	1.15	8,030	0	8,030	1.94	2.17	1.50	0.69	5.92	Yes	Yes	No
07-05-81	2019	1.87	11,434	0	11,434	1.70	4.00	1.18	0.30	3.08	No	No	No
07-07-81	0345	1.62	1,430	0	1,430	0.25	2.33	0.19	0.08	1.04	No	No	No
07-10-81	1700	1.07	2,023	0	2,023	0.53	0.67	0.27	0.40	3.46	No	No	No
07-16-81	1507	1.87	1,825	0	1,825	0.27	2.67	0.17	0.06	0.33	No	No	No
07-20-81	1621	0.82	1,782	0	1,782	0.60	1.67	0.40	0.24	3.88	No	No	No
08-06-81	1011	1.60	1,911	0	1,911	0.33	1.67	0.37	0.22	4.00	Yes	Yes	No
08-20-81	2247	1.58	14,356	0	14,356	2.52	8.00	1.30	0.16	2.08	Yes	Yes	Yes
09-01-81	1050	2.23	3,395	0	3,395	0.42	1.50	0.42	0.28	11.17	No	No	No
09-03-81	1743	1.02	1,138	0	1,138	0.31	7.00	0.33	0.05	1.67	No	No	No
09-06-81	2004	0.82	11,221	0	11,221	3.80	1.33	0.56	0.42	0.29	No	No	No
09-15-81	0202	13.78	14,373	0	14,373	0.29	8.00	0.95	0.12	8.04	Yes	Yes	Yes
09-15-81	1746	4.65	16,123	0	16.123	0.96	6.00	0.86	0.14	0.29	Yes	Yes	Yes
10-01-81	2216	2.47	3,565	0	3,565	0.40	4.50	0.40	0.09	15.83	Yes	Yes	Yes
10-05-81	1226	1.57	2,154	0	2,154	0.38	2.33	0.35	0.15	3.38	No	No	No
10-23-81	0412	10.57	9,467	0	9,456	0.25	9.33	0.98	0.11	3.75	Yes	Yes	Yes
10-25-81	1852	15.37	15,595	0	15,595	0.28	10.67	0.99	0.09	0.25	No	No	No
10-26-81	1931	6.14	19,391	0	19,391	0.88	4.83	0.81	0.17	0.38	Yes	Yes	Yes
11-19-81	2259	1.57	2,638	0	2,638	0.47	1.00	0.22	0.22	3.04	Yes	Yes	No
11-23-81	2314	3.22	4,993	0	4,993	0.43	6.00	0.46	0.08	3.71	Yes	Yes	No
12-01-81	0439	6.32	13,613	0	13,613	0.60	6.50	0.68	0.10	0.38	Yes	Yes	Yes
01-20-82	2234	8.85	26,142	0	26,142	0.82	b	b	b	b	Yes	Yes	No
01-23-82	0708	26.95	18,905	0	18,905	0.19	b	b	b	b	Yes	Yes	No
02-02-82	1112	16.78	23,033	0	23,033	0.38	b	b	b	b	Yes	Yes	Yes
02-09-82	0408	14.32	24,829	0	24,829	0.48	7.0	1.00	0.14	2.83	Yes	Yes	No
03-21-82	0528	6.88	18,024	0	18,024	0.73	6.66	0.91	0.14	1.25	Yes	Yes	No
03-25-82	1743	1.03	3,150	0	3,150	0.85	0.5	0.22	0.44	4.25	Yes	Yes	No
03-31-82	0623	3.38	5,533	0	5,533	0.45	3.33	0.41	0.12	5.46	Yes	Yes	No
04-17-82	0835	5.90	12,784	0	12,784	0.60	5.90	0.76	0.12	1.46	Yes	Yes	No

a. Began monthly dryfall collection in November 1981.
b. Record lost due to equipment malfunction.

Storm Event Summaries
Residential 2 (R2) Site

Beginning		Runoff duration (hrs)	Total volume (ft^3)			Average flow (cfs)	Rainfall duration (hrs)	Total rainfall (in)	Average intensity (in/hr)	Antecedent dry period (days)	Samples collected		
Date	Time		Runoff + Base	Base	Runoff						Water	Wetfall	Dryfall[a]
05-14-81	1932	2.43	5,147	0	5,147	0.59	b	b	b	b	No	No	No
05-18-81	2100	8.88	8,836	0	8,836	0.28	9.00	0.75	0.08	4.08	No	No	No
05-20-81	1020	9.50	5,045	0	5,045	0.15	14.00	0.60	0.04	0.33	No	No	No
05-27-81	1441	11.10	30,361	0	30,361	0.76	b	b	b	b	No	No	No
05-30-81	1709	3.07	7,485	0	7,485	0.68	1.33	0.61	0.46	2.54	No	No	No
06-02-81	0130	18.85	20,781	0	20,781	0.31	10.00	1.20	0.12	1.21	No	No	No
06-04-81	0658	14.70	18,544	0	18,544	0.35	8.00	0.98	0.12	1.38	No	No	No
06-06-81	0602	16.07	153,483	0	153,483	2.65	b	b	b	1.33	No	No	No
06-25-81	1631	4.07	6,906	0	6,906	0.47	3.50	0.66	0.19	2.67	No	No	No
07-01-81	0100	2.28	9,159	0	9,159	1.12	1.5	0.79	0.53	5.13	No	No	No
07-01-81	2049	4.12	16,504	0	16,504	1.11	2.17	0.89	0.41	0.71	Yes	Yes	Yes
07-05-81	2021	4.98	16,321	0	16,321	0.91	5.67	1.38	0.24	3.08	No	No	No
07-15-81	1911	2.15	1,509	0	1,509	0.19	2.50	0.22	0.09	1.92	No	No	No
07-16-81	1453	3.93	2,984	0	2,984	0.21	1.00	0.29	0.29	0.29	No	No	No
08-06-81	0950	1.72	2,658	0	2,658	0.43	1.83	0.38	0.21	3.92	Yes	Yes	Yes
08-11-81	2137	3.58	7,657	0	7,657	0.59	1.17	0.47	0.40	3.75	Yes	Yes	Yes
08-12-81	0521	4.17	5,166	0	5,166	0.34	2.00	0.15	0.08	0.25	No	No	No
08-20-81	2220	7.93	20,227	0	20,227	0.71	7.67	1.40	0.18	2.08	Yes	Yes	Yes
09-03-81	1735	1.30	10,152	0	10,152	2.17	1.50	0.59	0.39	2.17	No	No	No
09-06-81	1154	9.83	19,073	0	19,073	0.54	1.83	1.60	0.87	2.13	No	No	No
09-15-81	0145	9.55	20,346	0	20,346	0.59	8.00	1.20	0.15	8.04	Yes	Yes	Yes
09-15-81	1726	1.95	15,550	0	15,550	2.22	6.00	0.84	0.14	0.13	Yes	Yes	Yes
10-01-81	2125	2.93	2,765	0	2,765	0.26	3.50	0.34	0.10	15.83	Yes	Yes	Yes
10-18-81	0433	2.65	2,909	0	2,909	0.30	4.50	0.41	0.09	12.50	No	No	No
10-23-81	0303	10.68	15,327	0	15,327	0.40	9.00	0.93	0.10	2.71	Yes	Yes	Yes
10-25-81	0944	27.57	31,440	0	31,440	0.32	14.00	1.39	0.10	1.83	No	No	No
10-26-81	1910	9.55	13,524	0	13,524	0.39	5.00	0.53	0.11	0.33	No	No	No
10-27-81	0742	2.62	593	0	593	0.06	0.50	0.08	0.16	0.33	Yes	Yes	Yes
11-23-81	2223	3.97	5,626	0	5,626	0.39	3.00	0.40	0.13	3.92	Yes	Yes	No
01-22-82	0635	42.83	30,249	0	30,249	0.20	8.0	0.98	0.12	0.96	Yes	Yes	No
02-02-82	1037	37.82	28,730	0	28,730	0.21	16.0	1.07	0.07	1.71	Yes	Yes	Yes
02-09-82	0348	28.25	28,964	0	28,964	0.28	7.0	0.97	0.14	2.21	Yes	Yes	No
03-21-82	0457	13.17	32,635	0	32,635	0.69	6.0	1.00	0.17	4.00	Yes	Yes	No
03-25-82	1730	5.50	11,003	792	10,211	0.56	0.50	0.30	0.60	4.25	Yes	Yes	No
03-31-82	0542	7.32	16,738	0	16,738	0.64	3.67	0.50	0.14	5.46	Yes	Yes	No
04-15-82	2012	5.42	8,206	0	8,206	0.42	0.50	0.40	0.80	1.17	Yes	Yes	No
04-17-82	0829	13.88	17,863	0	17,863	0.36	5.67	0.71	0.13	1.46	Yes	Yes	No

a. Began monthly dryfall collection in November 1981.
b. Record lost due to equipment malfunction.

Storm Event Summaries
Strip Commercial (SC) Site

Beginning		Runoff duration (hrs)	Total volume (ft^3)			Average flow (cfs)	Rainfall duration (hrs)	Total rainfall (in)	Average intensity (in/hr)	Antecedent dry period (days)	Samples collected		
Date	Time		Runoff + Base	Base	Runoff						Water	Wetfall	Dryfall[a]
04-17-81	0706	5.42	59,307	780	58,527	3.04	4.50	0.78	0.17	0.71	No	No	No
04-18-81	0649	2.18	12,827	314	12,513	1.63	1.33	0.20	0.15	0.75	No	No	No
04-19-81	1735	13.12	59,134	1,889	57,245	1.25	10.00	0.83	0.08	1.21	No	No	No
04-23-81	0402	2.33	13,921	336	13,585	1.66	1.33	0.19	0.14	0.29	No	No	No
05-10-81	1856	6.00	15,904	864	15,040	0.74	2.00	0.26	0.13	3.75	No	No	No
05-14-81	2013	3.85	48,924	554	48,370	3.53	b	b	b	b	No	No	No
05-18-81	0040	2.58	4,101	372	3,729	0.44	b	b	b	b	No	No	No
05-19-81	0011	9.37	77,557	1,349	76,208	2.30	b	b	b	b	No	No	No
05-20-81	0958	9.78	50,555	1,409	49,146	1.44	b	b	b	b	No	No	No
05-25-81	1330	2.35	7,223	338	6,885	0.85	2.00	0.13	0.07	b	No	No	No
05-26-81	2122	8.22	25,110	1,183	23,927	0.85	b	b	b	b	No	No	No
05-27-81	1308	11.05	136,300	1,591	134,709	3.43	b	b	b	b	No	No	No
05-30-81	1653	2.57	51,460	370	51,090	5.56	b	b	b	b	No	No	No
05-31-81	1833	3.38	9,236	487	8,749	0.76	b	b	b	b	No	No	No
06-02-81	0139	22.07	125,292	3,178	122,114	1.58	b	b	b	b	No	No	No
06-04-81	0342	12.42	52,104	1,788	50,316	1.17	2.00	0.48	0.24	1.38	No	No	No
06-04-81	1611	6.63	50,529	955	49,574	2.12	0.50	0.50	1.00	0.29	No	No	No
06-06-81	0414	17.85	342,475	767	341,708	5.33	8.00	2.38	0.30	1.33	No	No	No
06-10-81	1714	7.90	29,392	1,138	28,254	1.03	4.93	0.32	0.06	3.96	No	No	No
06-12-81	0513	4.05	1,082	583	499	0.07	0.50	0.12	0.24	1.17	No	No	No
06-22-81	2100	3.50	8,710	504	8,206	0.69	2.50	0.13	0.05	1.54	No	No	No
06-25-81	1603	7.42	61,185	1,068	60,117	2.29	b	b	b	b	No	No	No
07-01-81	0053	9.82	53,647	1,414	52,233	1.52	b	b	b	b	No	No	No
07-01-81	2044	11.58	84,424	1,668	82,756	2.03	b	b	b	b	No	No	No
07-02-81	1513	2.95	8,432	425	8,007	0.79	b	b	b	b	No	No	No
07-05-81	1826	12.50	83,303	1,800	81,503	1.85	6.50	1.00	0.15	3.08	No	No	No
07-07-81	0313	8.60	11,042	1,238	9,804	0.36	1.33	0.13	0.10	0.29	No	No	No
07-15-81	1702	5.45	28,932	785	28,147	1.47	1.50	0.30	0.20	1.04	No	No	No
07-16-81	0615	4.83	10,902	696	10,206	0.63	0.33	0.12	0.36	0.42	No	No	No
07-16-81	1448	9.08	25,620	1,308	24,312	0.78	0.83	0.25	0.30	0.29	No	No	No
07-20-81	1552	6.37	49,007	528	48,479	2.14	0.50	0.49	0.98	3.96	No	No	No
08-02-81	0608	4.40	49,484	634	48,850	3.12	4.00	0.55	0.14	4.21	No	No	No
08-06-81	0932	4.90	32,135	706	31,429	1.82	2.33	0.35	0.15	3.83	Yes	Yes	Yes
08-06-81	1824	2.45	12,840	353	12,487	1.46	0.33	0.13	0.39	0.21	No	No	No
08-08-81	0008	3.30	23,349	475	22,874	1.97	5.83	0.35	0.06	1.04	Yes	Yes	Yes
08-11-81	2139	1.35	35,674	194	35,480	7.34	3.00	0.37	0.12	4.08	Yes	Yes	Yes
08-15-81	1456	0.93	5,129	134	4,995	1.53	1.00	0.10	0.10	3.29	No	No	No
08-16-81	1004	8.08	7,939	1,164	6,775	0.27	0.67	0.13	0.19	0.71	No	No	No

a. Began monthly dryfall collection in November 1981.
b. Record lost due to equipment malfunction.

Storm Event Summaries
Strip Commercial (SC) Site

(Continued)

Beginning		Runoff duration (hrs)	Total volume (ft^3)			Average flow (cfs)	Rainfall duration (hrs)	Total rainfall (in)	Average intensity (in/hr)	Antecedent dry period (days)	Samples collected		
Date	Time		Runoff + Base	Base	Runoff						Water	Wetfall	Dryfall[a]
08-18-81	1518	3.43	11,474	495	10,979	0.93	2.50	0.25	0.10	1.88	Yes	Yes	Yes
08-20-81	2158	13.20	144,693	1,901	142,792	3.04	11.00	1.41	0.13	2.13	Yes	Yes	Yes
09-01-81	0903	7.90	46,570	1,138	45,432	1.64	2.50	0.53	0.21	10.25	No	No	No
09-03-81	1739	6.93	68,080	998	67,082	2.73	0.33	0.80	2.42	2.13	No	No	No
09-06-81	1148	10.02	106,733	1,442	105,291	2.96	1.50	1.06	0.71	2.71	No	No	No
09-14-81	2158	27.72	221,452	3,991	217,461	2.22	b	b	b	b	No	No	No
09-15-81	1714	8.47	78,703	1,219	77,484	2.58	b	b	b	b	Yes	Yes	Yes
10-01-81	0939	7.20	31,678	1,037	30,641	1.22	2.50	0.35	0.14	15.79	Yes	Yes	Yes
10-05-81	1152	4.80	15,717	691	15,026	0.91	2.5	0.24	0.10	4.17	No	No	No
10-18-81	0401	15.23	36,510	2,194	34,316	0.67	6.00	0.45	0.08	11.71	No	No	No
10-22-81	2204	29.77	110,860	4,286	106,574	1.03	8.50	0.91	0.11	3.88	Yes	Yes	Yes
10-25-81	0911	6.55	7,131	943	6,188	0.30	2.00	0.11	0.06	1.83	No	No	No
10-25-81	1801	24.52	154,927	3,530	151,397	1.76	10.00	1.26	0.13	0.25	No	No	No
10-26-81	1853	23.65	77,414	3,406	74,008	0.91	5.50	0.58	0.11	0.33	Yes	Yes	Yes
11-23-81	2021	11.03	46,291	1,588	44,703	1.17	5.17	0.48	0.09	3.67	Yes	Yes	No
12-01-81	0313	17.75	106,015	2,556	103,459	1.66	6.67	0.70	0.10	0.38	Yes	Yes	Yes
01-22-82	0635	41.90	134,535	5,986	128,549	0.89	10.0	0.98	0.10	b	Yes	Yes	No
02-02-82	1032	36.73	158,249	5,289	152,960	1.20	b	b	b	b	Yes	Yes	
02-09-82	0354	27.52	144,283	3,963	140,320	1.46	10.0	1.00	0.10	2.83	Yes	Yes	No
03-21-82	0447	10.43	122,236	1,502	120,734	3.25	6.66	1.00	0.15	4.00	Yes	Yes	
03-25-82	1730	13.28	47,534	1,912	45,622	0.33	1.00	0.33	0.10	4.20	Yes	Yes	
03-31-82	0542	10.18	64,091	1,466	62,625	1.75	3.66	0.58	0.16	5.33	Yes	Yes	
04-08-82	0659	12.02	33,728	1,731	31,997	0.78	5.50	0.30	0.06	7.54	Yes		
04-15-82	2018	9.70	49,82[illegible]	1,396	48,424	1.43	2.50	0.50	0.20	1.04	Yes	Yes	
04-17-82	0828	19.03	105,4[illegible]	2,740	102,723	1.54	5.00	0.80	0.16	1.46		Yes	

a. Began monthly dryfall collection in November 1981.
b. Record lost due to equipment malfunction.

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APPENDIX E

CONCENTRATION DATA FOR DISCRETE AND COMPOSITE URBAN RUNOFF SAMPLES

Water Quality Data
Discrete Samples Collected at the Central Business District District (CBD) Site

Storm number	Date collected	Sample number	pH	Conductivity (µmhos at 25°C)	TDS (mg/L)	TSS (mg/L)	NO_2+NO_3-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	DKN (mg/L)	TP (mg/L)	DP (mg/L)	SOC (mg/L)	TOC (mg/L)	COD (mg/L)
11	10-23-81	1	7.0	170	130	120	1.20	0.41	1.00	0.68	0.22	0.08	14.0	19.0	93
		2	6.8	120	80	40	0.85	0.39	0.80	0.50	0.13	0.04	10.0	13.0	52
		3	7.2	95	80	210	0.54	0.26	0.56	0.32	0.26	0.04	10.0	12.0	78
		4	6.8	88	70	120	0.47	0.24	0.52	0.36	0.19	0.04	10.0	15.0	71
		5	6.8	77	50	36	0.47	0.20	0.36	0.30	0.08	0.03	6.5	8.8	22
		6	7.0	74	60	76	0.36	0.14	0.36	0.26	0.13	0.02	9.7	12.0	35
		7	6.9	75	60	97	0.40	0.16	0.42	0.20	0.16	0.02	9.9	13.0	48
		8	6.8	72	50	55	0.41	0.16	0.62	0.18	0.10	0.03	6.7	9.4	26
		9	6.8	69	40	32	0.34	0.13	0.34	0.18	0.08	0.03	3.0	5.8	16
		10	6.8	63	50	380	0.31	0.14	0.30	0.20	0.06	0.03	3.8	4.8	8
		11	7.0	78	60	80	0.33	0.13	0.46	0.16	0.14	0.02	3.8	6.1	20
		12	6.9	83	60	16	0.44	0.13	0.30	0.20	0.08	0.02	4.5	5.1	7
		13	7.1	110	80	110	0.52	0.20	0.50	0.20	0.22	0.02	5.0	9.0	57
		14	6.9	99	70	42	0.51	0.24	0.54	0.22	0.11	0.01	5.2	8.8	40
		15	6.9	99	80	38	0.52	0.19	0.42	0.22	0.11	0.01	5.3	7.6	42
		16	7.0	110	80	53	0.50	0.19	0.40	0.24	0.19	0.02	6.0	10.0	54
		17	7.0	100	80	41	0.46	0.16	0.58	0.24	0.17	0.01	21.0	32.0	78
		18	6.9	99	80	37	0.46	0.27	0.54	0.26	0.17	0.02	5.7	7.6	29
		19	6.8	98	80	31	0.46	0.16	0.34	0.28	0.15	0.02	5.3	7.7	30
		20	6.9	99	80	44	0.42	0.15	0.42	0.30	0.12	0.02	12.0	17.0	56
		21	7.0	86	60	37	0.34	0.12	0.26	0.22	0.12	0.02	4.8	6.8	32
		22	6.8	93	70	47	0.67	0.12	0.32	0.22	0.31	0.12	5.9	12.0	47
		23	6.8	81	60	39	0.44	0.13	0.38	0.24	0.42	0.23	4.9	7.5	35
		24	7.0	92	80	51	0.35	0.13	0.34	0.18	0.20	0.05	4.5	8.1	29
21	03-21-82	1	6.5		50	230	0.70	0.05	1.00		0.32			46	230
		2	6.5		90	100	0.44	0.11	0.73		0.18			31	100
		3	6.3		50	30	0.44	0.14	0.44		0.10			28	65
		4	6.2		70	50	0.24	0.05	0.41		0.07			17	54
		5	6.3		20	40	0.40	0.07	0.18		0.08			7.8	31
		6	6.4		50	40	0.19	0.04	0.29		0.08			11	31
		7	6.4		30	40	0.32	0.08	0.16		0.06			17	40
		8	Insufficient sample												
		9	6.0		50	19	0.28	0.09	0.24		0.06			7.0	20
		10	6.7		20	11	0.36	0.06	0.20		0.05			7.8	14
		11	6.2		<10	10	0.39	0.07	0.24		0.06			11	20
		12	6.3		30	23	0.14	0.05	0.28		0.07			15	32

Water Quality Data
Discrete Samples Collected at the Central Business District (CBD) Site

Storm number	Date collected	Sample number	pH	Conductivity (µmhos at 25°C)	TDS (mg/L)	TSS (mg/L)	NO_2+NO_3-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	DKN (mg/L)	TP (mg/L)	DP (mg/L)	SOC (mg/L)	TOC (mg/L)	COD (mg/L)
24	04-01-82	1	6.5	230	130	290	0.89	0.07	0.64		0.40			40	170
		2	6.4	220	120	290	0.76	0.07	0.60		0.25			34	150
		3	6.4	160	70	240	0.40	0.09	0.46		0.25			14	130
		4	6.3	120	80	120	0.40	0.22	0.39		0.15			10	64
		5	6.4	100	50	65	0.40	0.12	0.44		0.13			11	35
		6	6.4	130	70	72	0.55	0.11	0.46		0.15			11	59
		7	6.3	160	90	100	0.66	0.40	0.78		0.15			11	32
25	04-09-82	1	6.5	160	90	90								20	95
		2	6.4	120	70	43								5.3	81
27	04-17-82	1	6.8	260	100	550									
		2	6.4	120	60	70									
		3	6.3	100	60	76									
		4	6.6	84	20	60									
		5	6.6	100	60	31									
		6	6.6	120	80	22									
		7	7.2	120	70	23									
		8	6.7	180	90	340									
		9	6.6	120	80	48									

Water Quality Data
Discrete Samples Collected at the Central Business District (CBD) Site

Storm number	Date collected	Sample number	Fecal coliform (bacteria/100 ml)	Fecal strep (bacteria/100 ml)	BOD$_5$ (mg/L)	Total alkalinity (mg/L as CaCO$_3$)	SO$_4$ (mg/L)	Cl (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)
11	10-23-81	1	3,000	33,000	16.0	50	21	6	36.9	4.48	3.61	4.2
		2	12,000	52,000	12.0	34	18	4	19.0	1.93	3.05	2.6
		3	16,000	87,000	12.0	38	13	2	32.7	4.40	1.34	2.4
		4	16,000	46,000	7.8	34	11	3	20.2	2.17	1.39	2.2
		5	17,000	50,000	5.0	32	11	2	12.8	1.46	1.24	1.7
		6	14,000	26,000	5.4	30	9	1	20.0	2.42	0.97	1.7
		7	32,000	5,000	6.0	30	9	1	22.3	2.97	1.02	1.7
		8	23,000	10,000	3.8	30	10	1	13.7	1.56	0.96	1.5
		9	40,000	7,000	3.0	24	10	1	11.6	1.42	0.96	1.6
		10	40,000	8,000	3.0	24	9	<1	10.3	1.19	0.94	1.5
		11	34,000	17,000	3.6	30	9	1	15.4	1.98	1.02	2.1
		12	5,000	3,000	3.2	28	12	2	12.9	1.55	1.83	2.0
		13	10,000	9,000	7.6	44	12	2	23.1	2.67	1.28	2.7
		14	5,000	2,000	5.4	40	11	2	17.4	1.89	1.14	2.2
		15	6,000	7,000	6.0	38	10	2	17.9	1.87	1.22	2.2
		16	3,000	10,000	5.6	40	10	2	22.4	2.42	1.29	2.3
		17	4,000	11,800	6.0	42	12	2	18.9	1.96	1.46	2.2
		18	2,400	9,000	5.8	40	11	2	16.8	1.71	1.18	2.1
		19	3,000	23,000	5.6	38	11	2	16.5	1.67	1.44	2.0
		20	3,800	14,000	7.2	44	10	2	23.4	2.52	1.44	2.0
		21	5,600	20,000	5.2	36	9	2	16.5	1.66	1.17	1.8
		22	5,800	24,000	5.6	36	10	2	17.0	1.75	1.43	2.0
		23	6,200	26,000	5.8	34	10	2	15.8	1.68	1.52	2.3
		24	3,600	38,000	4.6	38	7	2	16.7	1.80	1.34	2.2
21	03-21-82	1	6,100		72	62						
		2	2,200		29	44						
		3	2,800		12	31						
		4	4,300		13	35						
		5	1,400		6.8	28						
		6	1,600		14	34						
		7	2,400		8	26						
		8	Insufficient sample									
		9	3,200		9	26						
		10	2,400		6	24						
		11	4,700		11	28						
		12	3,400		12	32						

Water Quality Data
Discrete Samples Collected at the Central Business District (CBD) Site

Storm number	Date collected	Sample number	Fecal coliform (bacteria/100 ml)	Fecal strep (bacteria/100 ml)	BOD_5 (mg/L)	Total alkalinity (mg/L as $CaCO_3$)	SO_4 (mg/L)	Cl (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)
24	04-01-82	1	2,000		33	44						
		2	1,500		19	40						
		3	500		17	36						
		4	300		9.4	30						
		5	600		9.6	26						
		6	950		8.6	32						
		7	1,200		7.8	44						
25	04-09-82	1	2,800			42						
		2	2,600			34						
27	04-17-82	1	3,400			92						
		2	3,400			31						
		3	3,000			34						
		4	3,800			27						
		5	2,000			28						
		6	2,300			28						
		7	3,000			32						
		8	500			59						
		9	1,900			36						

Water Quality Data
Discrete Samples Collected at the Central Business District (CBD) Site

Storm number	Date collected	Sample number	Cu (µg/L)			Zn (µg/L)			Cr (µg/L)			Se (µg/L)		
			Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
11	10-23-81	1	84			378			230			<1		
		2	20			183			100			<1		
		3	36			409			140			<1		
		4	29			254			32			<1		
		5	29			134			59			<1		
		6	22			221			56			<1		
		7	38			329			140			<1		
		8	16			206			21			<1		
		9	11			112			49			<1		
		10	4			106			40			<1		
		11	23			157			43			<1		
		12	10			94			80			<1		
		13	25			266			16			<1		
		14	28			164			18			<1		
		15	16			168			16			<1		
		16	16			181			27			<1		
		17	23			188			25			<1		
		18	20			161			27			<1		
		19	16			526			40			<1		
		20	37			164			30			<1		
		21	16			141			24			<1		
		22	17			171			22			<1		
		23	14			161			24			<1		
		24	15			162			29			<1		
21	03-21-82	1												
		2												
		3												
		4												
		5												
		6												
		7												
		8												
		9												
		10												
		11												
		12												

Water Quality Data
Discrete Samples Collected at the Central Business District (CBD) Site

Storm number	Date collected	Sample number	Cu (µg/L)			Zn (µg/L)			Cr (µg/L)			Se (µg/L)		
			Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
24	04-01-82	1												
		2												
		3												
		4												
		5												
		6												
		7												
25	04-09-82	1												
		2												
27	04-17-82	1												
		2												
		3												
		4												
		5												
		6												
		7												
		8												
		9												

Water Quality Data
Discrete Samples Collected at the Central Business District (CBD) Site

Storm number	Date collected	Sample number	Hg (µg/L)			Ni (µg/L)			Cd (µg/L)			Pb (µg/L)		
			Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
11	10-12-81	1	<0.2			<50			2.3			190		
		2	<0.2			<50			0.8			77		
		3	<0.2			<50			2.0			340		
		4	<0.2			<50			<0.1			<1		
		5	<0.2			<50			0.8			55		
		6	<0.2			<50			1.1			90		
		7	<0.2			<50			1.8			120		
		8	<0.2			<50			0.5			2		
		9	<0.2			<50			0.6			52		
		10	<0.2			<50			0.5			39		
		11	<0.2			<50			0.6			54		
		12	<0.2			<50			0.2			41		
		13	<0.2			<50			1.3			120		
		14	<0.2			<50			0.8			93		
		15	<0.2			<50			0.6			77		
		16	<0.2			<50			0.7			88		
		17	<0.2			<50			0.9			86		
		18	<0.2			<50			1.0			83		
		19	<0.2			<50			0.6			78		
		20	<0.2			<50			0.6			350		
		21	<0.2			<50			<0.1			2		
		22	<0.2			<50			0.1			2		
		23	<0.2			<50			0.6			67		
		24	<0.2			<50			0.9			79		
21	03-21-82	1												
		2												
		3												
		4												
		5												
		6												
		7												
		8												
		9												
		10												
		11												
		12												

Water Quality Data
Discrete Samples Collected at the Central Business District (CBD) Site

Storm number	Date collected	Sample number	Hg (µg/L)			Ni (µg/L)			Cd (µg/L)			Pb (µg/L)		
			Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
24	04-01-82	1												
		2												
		3												
		4												
		5												
		6												
		7												
25	04-09-82	1												
		2												
27	04-17-82	1												
		2												
		3												
		4												
		5												
		6												
		7												
		8												
		9												

Water Quality Data
Discrete Samples Collected at the Central Business District (CBD) Site

Storm number	Date collected	Sample number	Fe (µg/L)			Mn (µg/L)			Al (µg/L)		
			Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
11	10-23-81	1	2550			138			1590		
		2	1500			51			550		
		3	3620			171			1800		
		4	2420			90			1180		
		5	936			36			460		
		6	2130			79			980		
		7	3240			98			1270		
		8	1310			42			620		
		9	980			32			490		
		10	1190			26			560		
		11	3390			79			1190		
		12	1200			23			540		
		13	3310			100			1570		
		14	1460			50			730		
		15	1850			51			730		
		16	1990			67			1300		
		17	1870			60			780		
		18	1560			46			670		
		19	1560			43			920		
		20	1460			60			610		
		21	1280			43			570		
		22	1340			47			870		
		23	1500			46			720		
		24	1780			54			770		
21	03-21-82	1									
		2									
		3									
		4									
		5									
		6									
		7									
		8									
		9									
		10									
		11									
		12									

Water Quality Data
Discrete Samples Collected at the Central Business District (CBD) Site

Storm number	Date collected	Sample number	Fe (µg/L)			Mn (µg/L)			Al (µg/L)		
			Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
24	04-01-82	1									
		2									
		3									
		4									
		5									
		6									
		7									
25	04-09-82	1									
		2									
27	04-17-82	1									
		2									
		3									
		4									
		5									
		6									
		7									
		8									
		9									

Water Quality Data
Discrete Samples Collected at the Strip Commercial (SC) Site

Storm number	Date collected	Sample number	pH	Conductivity (µmhos at 25°C)	TDS (mg/L)	TSS (mg/L)	NO_2+NO_3-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	DKN (mg/L)	TP (mg/L)	DP (mg/L)	SOC (mg/L)	TOC (mg/L)	COD (mg/L)
11	10-23-81	1	7.3	190	140	29	1.30	0.47	1.20	0.64	0.75	0.49	19.0	30.0	82
		2	6.7	81	70	32	0.77	0.36	0.62	0.42	0.30	0.17	11.0	13.0	57
		3	6.7	79	60	51	0.69	0.32	0.64	0.32	0.32	0.15	9.5	12.0	60
		4	6.7	64	50	65	0.48	0.25	0.54	0.34	0.30	0.13	9.7	11.0	64
		5	6.5	58	40	58	0.35	0.21	0.56	0.24	0.20	0.12	13.0	17.0	65
		6	6.6	56	40	27	0.31	0.20	0.42	0.28	0.20	0.12	6.3	7.5	41
		7	6.6	51	40	57	0.22	0.11	0.26	0.18	0.17	0.07	10.0	18.0	64
		8	6.4	51	30	26	0.24	0.12	0.40	0.24	0.17	0.10	4.7	6.2	27
		9	6.5	52	30	7	0.21	0.22	0.46	0.34	0.13	0.13	4.4	5.4	13
		10	6.6	58	30	5	0.20	0.13	0.42	0.24	0.16	0.11	4.9	6.1	16
		11	7.0	83	50	14	0.39	0.18	0.42	0.24	0.19	0.12	5.0	7.6	27
		12	6.7	58	40	19	0.45	0.20	0.50	0.32	0.16	0.08	7.7	9.1	31
		13	6.8	73	60	12	0.34	0.19	0.36	0.28	0.12	0.07	5.4	6.6	22
		14	6.7	78	60	13	0.34	0.16	0.40	0.22	0.19	0.08	5.3	7.5	19
		15	6.6	79	50	6	0.32	0.18	0.50	0.26	0.22	0.10	11.0	16.0	26
		16	6.6	65	50	16	0.19	0.28	0.52	0.18	0.15	0.08	6.4	8.9	26
		17	7.1	68	50	18	0.18	0.16	0.30	0.18	0.20	0.11	11.0	15.0	38
		18	6.7	68	40	14	0.16	0.14	0.28	0.16	0.16	0.07	5.3	6.9	17
22	03-26-82	1	6.6	550	300	1700	0.03	2.30	19.00		10.0			64	650
		2	6.3	120	80	770	0.39	0.34	0.85		0.77			17	340
		3	6.3	130	70	440	0.35	0.29	0.69		0.57			14	140
		4	6.3	120	80	210	0.38	0.28	0.85		0.44			17	84
25	04-09-82	1	6.6	380	190	180								37	340
		2	6.3	170	100	86								43	120
		3	6.3	120	70	47								15	60
		4	6.3	160	60	42								14	49
26	04-16-82	1	6.9	400	230	510								41	310
		2	6.5	110	80	110								12	57
27	04-17-82	1	7.3	350	200	190									
		2	6.0	82	30	63									
		3	6.2	74	40	38									
		4	6.3	84	20	49									
		5	6.3	84	30	30									
		6	6.5	94	50	30									
		7	6.7	180	70	67									

Water Quality Data
Discrete Samples Collected at the Strip Commercial (SC) Site

Storm number	Date collected	Sample number	Fecal coliform (bacteria/100 ml)	Fecal strep (bacteria/100 ml)	BOD_5 (mg/L)	Total alkalinity (mg/L as $CaCO_3$)	SO_4 (mg/L)	Cl (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)
11	10-23-81	1	5,000	124,000	20	46	26	12	27.9	3.15	6.46	3.0
		2	5,000	120,000	14	26	10	3	14.2	1.14	1.58	1.4
		3	5,000	50,000	13	24	10	4	16.0	1.53	1.55	1.4
		4	2,000	32,000	8.2	24	7	2	17.5	1.81	0.84	1.2
		5	1,000	40,000	7.6	24	7	2	14.2	1.45	0.62	1.1
		6	3,000	20,000	5.8	22	7	2	11.4	1.00	0.46	1.1
		7	5,000	28,000	5.4	22	5	1	15.7	1.77	0.36	0.92
		8	2,000	30,000	5.6	20	6	2	10.0	0.894	0.48	1.1
		9	5,000	45,000	3.8	20	4	2	8.9	0.653	0.51	1.1
		10	5,000	44,000	5.2	24	8	<1	10.2	0.719	0.68	1.1
		11	4,000	54,000	4.0	34	7	2	14.7	1.06	0.72	1.2
		12	7,000	52,000	5.2	22	7	<1	10.7	0.774	0.66	1.1
		13	1,000	28,000	4.8	28	7	2	11.8	0.849	0.82	1.2
		14	2,600	34,000	5.0	30	7	2	11.9	0.902	1.04	1.2
		15	2,700	45,000	5.0	30	8	2	12.6	0.960	1.14	1.4
		16	3,400	36,000	4.8	26	6	2	11.0	0.815	0.67	1.1
		17	3,000	42,000	7.2	28	6	2	12.1	0.927	0.93	1.2
		18	4,000	37,000	5.6	28	6	2	11.0	0.882	0.79	1.0
22	03-26-82	1	1,900,000			270						
		2	145,000			50						
		3	110,000			46						
		4	38,000			43						
25	04-09-82	1	>200,000			100						
		2	130,000			41						
		3	64,000			28						
		4	65,000			31						
26	04-16-82	1	7,100			88						
		2	4,700			38						
27	04-17-82	1	1,200			74						
		2	2,600			19						
		3	4,800			26						
		4	3,700			30						
		5	5,100			30						
		6	5,000			34						
		7	3,600			66						

Water Quality Data
Discrete Samples Collected at the Strip Commercial (SC) Site

Storm number	Date collected	Sample number	Cu (µg/L)			Zn (µg/L)			Cr (µg/L)			Se (µg/L)		
			Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
11	10-23-81	1	25			120			3			<1		
		2	13			144			20			<1		
		3	17			177			3			<1		
		4	17			191			3			<1		
		5	35			192			5			<1		
		6	12			105			1			<1		
		7	17			165			2			<1		
		8	13			84			4			<1		
		9	16			48			2			<1		
		10	7			43			2			<1		
		11	26			60			3			<1		
		12	28			75			2			<1		
		13	6			65			<1			<1		
		14	6			67			<1			<1		
		15	12			88			<1			<1		
		16	6			82			1			<1		
		17	4			86			1			<1		
		18	6			69			<1			<1		
22	03-26-82	1												
		2												
		3												
		4												
25	04-09-82	1												
		2												
		3												
		4												
26	04-16-82	1												
		2												
27	04-17-82	1												
		2												
		3												
		4												
		5												
		6												
		7												

Water Quality Data
Discrete Samples Collected at the Strip Commercial (SC) Site

Storm number	Date collected	Sample number	Hg (µg/L)			Ni (µg/L)			Cd (µg/L)			Pb (µg/L)		
			Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
11	10-23-81	1	<0.2			<50			0.8			140		
		2	<0.2			<50			0.7			240		
		3	<0.2			<50			0.9			300		
		4	<0.2			<50			1.0			380		
		5	<0.2			<50			1.7			290		
		6	<0.2			<50			0.6			180		
		7	<0.2			<50			1.0			340		
		8	<0.2			<50			1.0			170		
		9	0.4			<50			0.3			54		
		10	<0.2			<50			0.8			40		
		11	<0.2			<50			0.4			68		
		12	<0.2			<50			0.5			140		
		13	<0.2			<50			0.4			89		
		14	<0.2			<50			0.7			93		
		15	<0.2			<50			0.2			86		
		16	<0.2			<50			0.4			120		
		17	<0.2			<50			3.7			120		
		18	<0.2			<50			0.4			103		
22	03-26-82	1												
		2												
		3												
		4												
25	04-09-82	1												
		2												
		3												
		4												
26	04-16-82	1												
		2												
27	04-17-82	1												
		2												
		3												
		4												
		5												
		6												
		7												

Water Quality Data
Discrete Samples Collected at the Strip Commercial (SC) Site

Storm number	Date collected	Sample number	Fe (µg/L)			Mn (µg/L)			Al (µg/L)		
			Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
11	10-23-81	1	648			42			360		
		2	866			53			510		
		3	1320			89			510		
		4	1470			96			590		
		5	1640			88			610		
		6	846			48			390		
		7	1450			94			530		
		8	691			43			270		
		9	293			21			150		
		10	255			20			440		
		11	376			25			210		
		12	680			37			370		
		13	550			26			230		
		14	672			29			260		
		15	630			34			320		
		16	895			34			320		
		17	812			34			420		
		18	516			29			220		
22	03-26-82	1									
		2									
		3									
		4									
25	04-09-82	1									
		2									
		3									
		4									
26	04-16-82	1									
		2									
27	04-17-82	1									
		2									
		3									
		4									
		5									
		6									
		7									

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Water Quality Data
Discrete Samples Collected at the Residential 1 (R1) Site

Storm number	Date collected	Sample number	pH	Conductivity (µmhos at 25°C)	TDS (mg/L)	TSS (mg/L)	NO_2+NO_3-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	DKN (mg/L)	TP (mg/L)	DP (mg/L)	SOC (mg/L)	TOC (mg/L)	COD (mg/L)
13	11-20-81	1	7.0	210	200	2500	0.44	0.30	6.2	0.82	3.3	0.28	37	89	1000
		2	6.7	160	170	660	0.43	0.22	3.0	0.60	1.4	0.21	37	72	370
		3	6.5	130	150	560	0.39	0.27	2.0	0.40	0.97	0.16	34	59	230
15	12-01-81	1	6.7	121	100	86	0.35	0.07	0.80	0.52	0.36	0.24	16	34	100
		2	6.7	88	80	320	0.14	0.04	0.98	0.28	0.53	0.14	11	28	130
		3	6.7	78	70	270	0.11	0.04	0.84	0.28	0.50	0.13	12	27	120
		4	6.7	74	80	210	0.15	0.05	0.70	0.18	0.42	0.12	10	18	77
		5	6.6	76	110	140	0.22	0.05	0.48	0.14	0.29	0.10	10	13	69
		6	6.5	72	90	180	0.20	0.03	0.48	0.16	0.30	0.09	9.3	14	57
		7	6.6	69	100	210	0.29	0.04	0.62	0.12	0.36	0.08	9.5	12	65
		8	6.6	64	60	190	0.22	0.04	0.58	0.12	0.32	0.08	9.5	13	51
		9	6.6	69	90	90	0.17	0.05	0.38	0.18	0.25	0.10	9.1	12	41
		10	6.6	66	60	100	0.19	0.06	0.38	0.14	0.22	0.10	7.6	11	37
		11	6.6	62	70	120	0.26	0.05	0.44	0.16	0.26	0.10	10	12	37
		12	6.6	67	70	100	0.17	0.06	0.52	0.24	0.25	0.12	11	14	41
21	03-21-82	1	7.1		70	440	0.22	0.10	0.76		0.40			33	110
		2	6.8		110	590	0.20	0.10	0.92		0.51			29	140
		3	6.8		80	520	0.17	0.11	0.10		0.46			15	100
		4	7.0		90	310	0.15	0.08	0.81		0.37			13	75
		5	6.6		90	310	0.16	0.08	0.64		0.31			12	70
		6	6.2		70	260	0.18	0.07	0.72		0.35			12	60
		7	6.7		80	270	0.18	0.16	0.70		0.30			19	91
		8	6.6		80	260	0.15	0.08	0.57		0.28			11	68
		9	6.6		30	230	0.11	0.08	0.48		0.25			10	58
		10	6.7		20	340	0.13	0.08	0.54		0.31			11	68
		11	6.5		120	360	0.12	0.08	0.65		0.34			12	54
		12	6.4		80	370	0.12	0.13	0.55		0.30			16	58
27	04-17-82	1	6.8	290	120	2500									
		2	6.4	130	60	440									
		3	6.4	120	40	360									
		4	6.2	98	40	230									

Water Quality Data
Discrete Samples Collected at the Residential 1 (R1) Site

Storm number	Date collected	Sample number	Fecal coliform (bacteria/100 ml)	Fecal strep (bacteria/100 ml)	BOD_5 (mg/L)	Total alkalinity (mg/L as $CaCO_3$)	SO_4 (mg/L)	Cl (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)
13	11-20-81	1	68,000	150,000	78	75	7	8	106	15.3	3.12	8.6
		2	48,000	170,000	62	49	11	4	36.4	4.51	1.75	5.4
		3	31,000	120,000	48	47	8	4	26.9	3.38	1.35	5.0
15	12-01-81	1	6,000	87,000	14	40	4	4	17.4	1.93	1.68	5.0
		2	11,000	85,000	16	35	3	4	15.2	1.81	0.68	5.0
		3	10,000	102,000	16	31	<1	4	13.7	1.69	0.55	4.4
		4	7,750	65,000	13	30	<1	3	12.0	1.43	0.49	4.1
		5	2,800	60,000	8.5	30	<1	2	11.6	1.32	0.78	3.5
		6	3,700	44,000	8.5	28	2	2	12.0	1.48	0.60	3.5
		7	3,500	48,000	9.0	26	<1	2	11.6	1.73	0.50	3.4
		8	2,700	37,000	8.5	24	3	2	10.9	1.31	0.53	3.5
		9	3,100	48,000	7.5	27	3	2	10.3	1.15	0.55	3.6
		10	2,000	63,000	6.2	25	3	2	9.86	1.14	0.58	3.2
		11	2,400	50,000	9.0	25	<1	2	9.01	0.987	0.44	3.2
		12	2,900	66,000	6.0	27	3	2	10.2	1.09	0.52	3.4
21	03-21-82	1	12,300		22	45						
		2	16,100		16	43						
		3	14,200		12	40						
		4	12,000		7.8	32						
		5	14,900		6.6	32						
		6	15,800		7.6	31						
		7	15,000		12	41						
		8	14,200		7.2	33						
		9	12,900		5.6	33						
		10	8,400		5.6	31						
		11	11,400		5.4	30						
		12	14,000		5.4	28						
27	04-17-82	1	96,000			110						
		2	100,000			45						
		3	56,000			42						
		4	14,000			36						

Water Quality Data
Discrete Samples Collected at the Residential 1 (R1) Site

Storm number	Date collected	Sample number	Cu (µg/L)			Zn (µg/L)			Cr (µg/L)			Se (µg/L)		
			Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
13	11-20-81	1	229			1870			26			<1		
		2	69			974			13			<1		
		3	52			570			12			<1		
15	12-01-81	1	24			90			3					
		2	26			194			5					
		3	29			174			6					
		4	23			149			11					
		5	15			106			6					
		6	19			125			2					
		7	26			161			4					
		8	22			146			9					
		9	16			102			4					
		10	14			138			4					
		11	13			84			4					
		12	22			72			2					
21	03-21-82	1												
		2												
		3												
		4												
		5												
		6												
		7												
		8												
		9												
		10												
		11												
		12												
27	04-17-82	1												
		2												
		3												
		4												

Water Quality Data
Discrete Samples Collected at the Residential 1 (R1) Site

Storm number	Date collected	Sample number	Hg (µg/L)			Ni (µg/L)			Cd (µg/L)			Pb (µg/L)		
			Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
13	11-20-81	1	2.3			<50			8.4			2000		
		2	1.0			<50			2.3			690		
		3	0.4			<50			1.3			410		
15	12-01-81	1	<0.2						0.4			143		
		2	0.6						0.6			220		
		3	0.3						0.6			210		
		4	0.3						0.6			220		
		5	0.2						0.4			100		
		6	0.4						0.4			150		
		7	<0.2						0.5			170		
		8	0.4						0.6			140		
		9	0.2						0.3			81		
		10	0.2						0.3			86		
		11	<0.2						0.3			83		
		12	0.2						0.2			63		
21	03-21-82	1												
		2												
		3												
		4												
		5												
		6												
		7												
		8												
		9												
		10												
		11												
		12												
27	04-17-82	1												
		2												
		3												
		4												

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Water Quality Data
Discrete Samples Collected at the Residential 1 (R1) Site

Storm number	Date collected	Sample number	Fe (µg/L) Total	Fe (µg/L) Dissolved	Fe (µg/L) Suspended	Mn (µg/L) Total	Mn (µg/L) Dissolved	Mn (µg/L) Suspended	Al (µg/L) Total	Al (µg/L) Dissolved	Al (µg/L) Suspended
13	11-20-81	1	43,200			2,820			24,500		
		2	8,220			646			5,500		
		3	9,360			673			5,900		
15	12-01-81	1	1,960			107			2,330		
		2	9,390			394			5,460		
		3	5,330			323			3,850		
		4	4,460			279			3,550		
		5	2,860			173			1,990		
		6	4,220			233			2,680		
		7	6,380			263			8,250		
		8	3,730			252			3,060		
		9	1,700			138			1,600		
		10	2,450			142			1,730		
		11	1,940			163			1,790		
		12	1,700			132			1,420		
21	03-21-82	1									
		2									
		3									
		4									
		5									
		6									
		7									
		8									
		9									
		10									
		11									
		12									
27	04-17-82	1									
		2									
		3									
		4									

Water Quality Data
Discrete Samples Collected at the Residential 2 (R2) Site

Storm number	Date collected	Sample number	pH	Conductivity (µmhos at 25°C)	TDS (mg/L)	TSS (mg/L)	NO_2+NO_3-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	DKN (mg/L)	TP (mg/L)	DP (mg/L)	SOC (mg/L)	TOC (mg/L)	COD (mg/L)
11	10-23-81	1	6.8	78	50	22	0.67	0.15	0.34	0.26	0.27	0.14	7.7	10.0	43
		2	6.5	67	40	34	0.52	0.14	0.38	0.16	0.22	0.10	5.6	8.8	34
		3	6.4	69	50	26	0.51	0.13	0.26	0.16	0.19	0.09	5.9	9.4	30
		4	6.4	62	40	27	0.41	0.11	0.22	0.14	0.17	0.09	4.6	7.1	23
		5	6.6	60	50	32	0.31	0.11	0.20	0.14	0.16	0.12	4.5	7.2	29
		6	6.6	66	50	26	0.35	0.05	0.16	0.14	0.18	0.10	4.6	7.1	23
		7	6.4	59	50	17	0.29	0.13	0.20	0.10	0.15	0.10	4.4	6.1	17
22	03-26-82	1	7.0	130	90	730	0.44	0.35	0.91		0.62			39	280
		2	6.5	150	70	520	0.80	0.35	0.86		0.54			46	230
		3	6.5	180	80	540	0.50	0.49	1.30		1.20			44	260
		4	6.6	120	80	340	0.47	0.35	0.84		0.41			30	140
		5	6.5	110	60	220	0.40	0.27	0.79		0.44			29	110
		6	6.5	92	70	110	0.40	0.23	0.64		0.27			15	68
		7	6.2	87	60	63	0.41	0.16	0.62		0.27			15	58
26	04-16-82	1	6.7	200	110	520								19	210
		2	6.5	110	80	240								24	110
		3	6.8	170	90	390								17	190
		4	6.7	140	90	220								14	120
		5	6.5	110	80	120								12	77
		6	6.4	87	70	67								12	60
		7	6.4	90	80	83								13	55
27	04-17-82	1	6.5	220	70	280									
		2	6.4	100	40	33									
		3	6.4	80	40	91									
		4	6.5	83	40	36									
		5	6.5	89	30	22									
		6	6.5	92	50	18									
		7	6.3	79	30	16									

Water Quality Data
Discrete Samples Collected at the Residential 2 (R2) Site

Storm number	Date collected	Sample number	Fecal coliform (bacteria/100 ml)	Fecal strep (bacteria/100 ml)	BOD_5 (mg/L)	Total alkalinity (mg/L as $CaCO_3$)	SO_4 (mg/L)	Cl (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)
11	10-23-81	1	6,000	30,000	10	26	7	2	12.4	1.07	1.05	2.2
		2	8,000	22,000	8.2	28	7	2	13.2	1.13	0.81	1.7
		3	5,000	14,000	7.0	23	7	2	12.3	1.09	0.73	2.0
		4	4,000	22,000	5.8	23	6	1	11.9	1.03	0.66	1.6
		5	4,000	26,000	5.6	25	6	1	12.2	1.02	0.45	1.4
		6	6,000	28,000	5.2	26	7	1	12.0	1.05	0.60	1.8
		7	7,000	12,000	4.4	23	6	<1	10.3	0.908	0.61	1.7
22	03-26-82	1				95						
		2				74						
		3				82						
		4				47						
		5				40						
		6				32						
		7				28						
26	04-16-82	1	1,200			74						
		2	800			36						
		3	7,400			56						
		4	3,800			50						
		5	3,800			40						
		6	5,400			28						
		7	4,000			28						
27	04-17-82	1	5,000			72						
		2	2,500			35						
		3	4,000			26						
		4	9,100			29						
		5	6,000			34						
		6	5,600			30						
		7	7,600			30						

Water Quality Data
Discrete Samples Collected at the Residential 2 (R2) Site

Storm number	Date collected	Sample number	Cu (µg/L)			Zn (µg/L)			Cr (µg/L)			Se (µg/L)		
			Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
11	10-23-81	1	12			76			<1			<1		
		2	10			105			1			<1		
		3	16			87			2			<1		
		4	66			104			2			<1		
		5	20			101			2			<1		
		6	24			85			1			<1		
		7	16			66			1			<1		
22	03-26-82	1												
		2												
		3												
		4												
		5												
		6												
		7												
26	04-16-82	1												
		2												
		3												
		4												
		5												
		6												
		7												
27	04-17-82	1												
		2												
		3												
		4												
		5												
		6												
		7												

Water Quality Data
Discrete Samples Collected at the Residential 2 (R2) Site

Storm number	Date collected	Sample number	Hg (µg/L)			Ni (µg/L)			Cd (µg/L)			Pb (µg/L)		
			Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
11	10-23-81	1	<0.2			<50			0.3			96		
		2	<0.2			<50			0.5			120		
		3	<0.2			<50			0.5			98		
		4	<0.2			<50			0.4			150		
		5	<0.2			<50			0.4			140		
		6	<0.2			<50			0.3			86		
		7	<0.2			<50			0.2			63		
22	03-26-82	1												
		2												
		3												
		4												
		5												
		6												
		7												
26	04-16-82	1												
		2												
		3												
		4												
		5												
		6												
		7												
27	04-17-82	1												
		2												
		3												
		4												
		5												
		6												
		7												

Water Quality Data
Discrete Samples Collected at the Residential 2 (R2) Site

Storm number	Date collected	Sample number	Fe (µg/L) Total	Fe (µg/L) Dissolved	Fe (µg/L) Suspended	Mn (µg/L) Total	Mn (µg/L) Dissolved	Mn (µg/L) Suspended	Al (µg/L) Total	Al (µg/L) Dissolved	Al (µg/L) Suspended
11	10-23-81	1	572			40			260		
		2	995			51			500		
		3	622			43			220		
		4	743			42			300		
		5	822			45			310		
		6	784			39			340		
		7	805			30			300		
22	03-26-82	1									
		2									
		3									
		4									
		5									
		6									
		7									
26	04-16-82	1									
		2									
		3									
		4									
		5									
		6									
		7									
27	04-17-82	1									
		2									
		3									
		4									
		5									
		6									
		7									

Water Quality Data
Composite Samples Collected at the Central Business District (CBD) Site

Storm number	Date collected	pH	Conductivity (µmhos at 25°C)	TDS (mg/L)	TSS (mg/L)	NO_2+NO_3-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	DKN (mg/L)	TP (mg/L)	DP (mg/L)	SOC (mg/L)	TOC (mg/L)	COD (mg/L)
Base	06-11-81	7.5	-	500	16	0.74	0.16	0.56	0.54	0.08	0.01	4.3	6.5	21
1	07-02-81	6.9	230	150	130	0.68	0.12	0.74	0.56	0.25	0.05	8.4	15.0	65
Base*	07-15-81	7.3	380	220	8	0.47	0.04	0.42	-	0.04	0.01	4.8	8.7	28
Base**	07-15-81	7.0	340	190	43	1.00	0.38	1.40	-	0.36	0.18	32.0	34.0	55
2	08-06-81	6.8	220	140	170	0.60	0.01	0.98	0.80	0.35	0.11	42.0	47.0	120
3	08-08-81	6.9	130	70	60	0.16	0.03	0.31	0.28	0.10	0.04	4.8	7.5	40
4	No sample													
5	08-16-81	7.5	170	89	360	0.78	0.22	0.82	0.42	0.28	0.02	7.0	9.1	95
6	08-18-81	6.9	190	130	120	1.60	0.21	1.30	0.47	0.34	0.06	14.0	18.0	62
7	08-21-81	6.1	170	110	100	0.85	0.15	0.62	0.60	0.21	0.06	11.0	13.0	78
8	09-15-81	6.8		110	63	0.78	0.05	0.61	0.41	0.15	0.04	14.0	18.0	64
9	No sample													
10	Priority pollutants													
11	Discrete samples--refer to table													
12	10-27-81	7.6	100	60	100	0.28	0.10	0.30	0.16	0.12	0.02	4.8	8.0	21
13	11-20-81	6.8	130	80	100	0.68	0.20	0.65	0.39	0.24	0.05	7.0	9.8	42
14	11-24-81	7.0	92	60	49	0.94	0.27	0.69	0.48	0.19	0.04	5.6	14.0	63
15	12-01-81	6.7	79	50	39	0.31	0.09	0.38	0.24	0.10	0.02	4.5	9.2	36
16	No sample													
17	01-23-82	6.7	160	105	125	0.40	0.14	0.65	0.17	0.20	0.01	9.4	16.0	85
18	Priority pollutants													
19	02-09-82	7.5	86	70	52	0.45	0.18	0.56	0.36	0.14	0.04	6.0	12.0	59
20	03-05-82	7.1	165	95	330							6.4	14.0	97
21	Discrete samples--refer to table													
22	No sample													
23	03-31-82	7.1	130	150	61	0.42	0.08	0.50	0.48	0.20	0.09	11.0	15.0	140
24	Discrete samples--refer to table													
25	Discrete samples--refer to table													
26	No sample													
27	Discrete samples--refer to table													

*Representative of night-time base flow

**Representative of day-time base flow

Water Quality Data
Composite Samples Collected at the Central Business District (CBD) Site

Storm number	Date collected	Fecal coliform (bacteria/100 ml)	Fecal strep (bacteria/100 ml)	BOD_5 (mg/L)	Total alkalinity (mg/L as $CaCO_3$)	SO_4 (mg/L)	Cl (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)
Base	06-11-81	-	-	3.4	70	51	310	70.5	9.46	23.40	4.3
1	07-02-81	1,600	>2,000	14.0	57	31	14	34.0	4.66	8.67	3.0
Base*	07-15-81	10	>2,000	10.0	-	44	28	36.8	7.62	22.60	2.5
Base**	07-15-81	3,800	76,000	10.0	76	42	24	35.5	6.20	20.00	2.9
2	08-06-81	16,000	>20,000	25.0	57	16	4	36.8	4.20	3.80	3.8
3	08-08-81	70,000	211,000	4.7	36	9	2	20.0	2.28	1.95	2.2
4	No sample										
5	08-16-81	80,000	80,000	26.0	38	17	3	42.0	5.90	2.19	3.1
6	08-18-81	32,000	440,000	15.0	40	30	6	32.8	4.05	5.02	4.6
7	08-21-81	29,000	65,000	7.0	55	15	3	34.7	3.80	2.70	3.1
8	09-15-81	440,000	680,000	12.0	38	19	5	23.9	3.11	3.14	2.6
9	No sample										
10	Priority pollutants										
11	Discrete samples--refer to table										
12	10-27-81	44,000	84,000		50	8	2	26.0	3.32	1.04	2.4
13	11-20-81	3,500	37,000	8.3	31	12	2	27.2	3.41	1.82	2.4
14	11-24-81	2,000	22,000	12.0	26	14	2	14.6	1.59	1.82	2.2
15	12-01-81	1,100	45,000	10.0	25	8	1	11.4	1.20	1.26	1.8
16	No sample										
17	01-23-82	603	15,500	15.0	47			23.0	3.1		
18	Priority pollutants										
19	02-09-82	160	9,000	18.0	26			14.0	1.5		
20	03-05-82	615	46,000	12.0	49			63.0	9.3		
21	Discrete samples--refer to table										
22	No sample										
23	03-31-82	2,000	11,000	18	27						
24	Discrete samples--refer to table										
25	Discrete samples--refer to table										
26	No sample										
27	Discrete samples--refer to table										

*Representative of night-time base flow

**Representative of day-time base flow

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Water Quality Data
Composite Samples Collected at the Central Business District (CBD) Site

Storm number	Date collected	Cu (µg/L)			Zn (µg/L)			Cr (µg/L)			Se (µg/L)		
		Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
Base	06-17-81	416			4690			11			<1		
1	07-02-81	120			364			94			<1		
Base*	07-15-81	14			66			570			<1		
Base**	07-15-81	33			310			653			<1		
2	08-06-81	56			514			300			<1		
3	08-08-81	32	22	17	187	7	151	101	80	40	<1	<1	<0.2
4	No sample												
5	08-16-81	60			487			210			<1		
6	08-18-81	39			463			99			<1		
7	08-21-81	31			269			74			<1		
8	09-15-81	31			264			160			<1		
9	No sample												
10	Priority pollutants												
11	Discrete samples--refer to table												
12	10-27-81	13			193			42					
13	11-20-81	24	8		269	50		32	32				
14	11-24-81	23			209			16					
15	12-01-81	17	20		132	66		6	4				
16	No sample												
17	01-23-82	51	5		306	77		18	3				
18	Priority pollutants												
19	02-09-82	35	13		230	60		6	2				
20	03-05-82	57	15		520	62		58	22				
21	Discrete samples--refer to table												
22	No sample												
23	03-31-82												
24	Discrete samples--refer to table												
25	Discrete samples--refer to table												
26	No sample												
27	Discrete samples--refer to table												

*Representative of night-time base flow

**Representative of day-time base flow

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Water Quality Data
Composite Samples Collected at the Central Business District (CBD) Site

Storm number	Date collected	Hg (µg/L) Total	Hg (µg/L) Dissolved	Hg (µg/L) Suspended	Ni (µg/L) Total	Ni (µg/L) Dissolved	Ni (µg/L) Suspended	Cd (µg/L) Total	Cd (µg/L) Dissolved	Cd (µg/L) Suspended	Pb (µg/L) Total	Pb (µg/L) Dissolved	Pb (µg/L) Suspended
Base	06-11-81	<0.2			<100			5.1			21		
1	07-02-81	<0.4			<100			1.5			150		
Base*	07-15-81	<0.2			<100			0.3			11		
Base**	07-15-81	<0.2			<100			1.6			80		
2	08-06-81	<0.2			<50			1.6			250		
3	08-08-81	<0.2	<0.2	<0.1	<50	<50	<10	1.0	0.1	0.3	90	3	93
4	No sample												
5	08-16-81	0.3			<50			1.6			260		
6	08-18-81	<0.2			<50			1.5			200		
7	08-21-81	<0.2			<50			0.7			130		
8	09-15-81	<0.2			<50			0.8			120		
9	No sample												
10	Priority pollutants												
11	Discrete samples--refer to table												
12	10-27-81	<0.2						0.9			120		
13	11-20-81	0.3	<0.2					0.8	0.4		109	6	
14	11-24-81	0.2						0.7			70		
15	12-01-81	<0.2	<0.2					0.5	0.2		65	4	
16	No sample												
17	01-23-82							1.3	0.6		175	10	
18	Priority pollutants												
19	02-09-82							1.1	0.4		100	<1	
20	03-05-82	0.3						3.4	0.3		370	2	
21	Discrete samples--refer to table												
22	No sample												
23	03-31-82												
24	Discrete samples--refer to table												
25	Discrete samples--refer to table												
26	No sample												
27	Discrete samples--refer to table												

*Representative of night-time base flow

**Representative of day-time base flow

Water Quality Data
Composite Samples Collected at the Central Business District (CBD) Site

Storm number	Date collected	Fe (µg/L) Total	Fe (µg/L) Dissolved	Fe (µg/L) Suspended	Mn (µg/L) Total	Mn (µg/L) Dissolved	Mn (µg/L) Suspended	Al (µg/L) Total	Al (µg/L) Dissolved	Al (µg/L) Suspended
Base	06-11-81	934			278					
1	07-02-81	2560			151					
Base*	07-15-81	172			20					
Base**	07-15-81	811			62					
2	08-06-81	5050			191					
3	08-08-81	2460	10	2400	83	<5	62			
4	No sample									
5	08-16-81	5510			197					
6	08-18-81	5110			165					
7	08-21-81	3300			118			1900		
8	09-15-81	2040			85					
9	No sample									
10	Priority pollutants									
11	Discrete samples--refer to table									
12	10-27-81	2760			95			1370		
13	11-20-81	4340	33		123	17		2100	60	
14	11-24-81	1980			68			950		
15	12-01-81	1200	68		43			770	<50	
16	No sample									
17	01-23-82	5850	46		190	21		2400	165	
18	Priority pollutants									
19	02-09-82	2500	22		84	20		1200	50	
20	03-05-82	9300	45		482	17		6600	65	
21	Discrete samples--refer to table									
22	No sample									
23	03-31-82									
24	Discrete samples--refer to table									
25	Discrete samples--refer to table									
26	No sample									
27	Discrete samples--refer to table									

*Representative of night-time base flow

**Representative of day-time base flow

Water Quality Data
Composite Samples Collected at the Strip Commercial (SC) Site

Storm number	Date collected	pH	Conductivity (µmhos at 25°C)	TDS (mg/L)	TSS (mg/L)	NO_2+NO_3-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	DKN (mg/L)	TP (mg/L)	DP (mg/L)	SOC (mg/L)	TOC (mg/L)	COD (mg/L)
Base	06-11-81	7.5	410	210	4	0.46	0.46	0.40	0.36	0.89	0.79	8.1	5.1	27
Base*	06-17-81	7.8	470	260	6	1.90	0.03	0.42	0.42	1.90	1.70	12.0	17.0	61
Base*	06-17-81	7.8	470	240	2	2.00	<0.01	0.51	0.37	1.70	1.40	12.0	24.0	59
1	No sample													
2	08-06-81	6.6	160	100	70	0.67	0.36	1.00	0.90	0.62	0.44	18.0	22.0	88
3	08-08-81	6.8	100	55	40	0.32	<0.01	0.48	0.48	0.28	0.18	5.6	7.3	42
4	08-12-81	7.0	150	76	4	0.70	0.03	0.58	0.30	0.44	0.18	6.1	10.0	80
5	No sample													
6	08-18-81	6.6	130	100	42	1.50	0.10	0.74	0.56	0.39	0.24	16.0	19.0	50
7	08-21-81	4.6	90	60	46	0.86	0.05	0.36	0.38	0.21	0.14	5.7	7.8	18
8	No sample													
9	09-16-81	7.0	68	29	36	0.17	0.12	0.28	0.28	0.12	0.05	4.7	6.4	14
10	Priority pollutants													
11	Discrete samples--refer to table													
12	10-27-81	7.1	78	60	37	0.21	0.13	0.42	0.24	0.18	0.09	4.8	6.3	22
13	No sample													
14	11-24-81	7.0	79	60	52	0.62	0.20	0.60	0.32	0.31	0.10	7.4	16.0	82
15	12-01-81	6.8	80	50	41	0.14	0.05	0.54	0.24	0.24	0.09	4.9	12.0	55
16	No sample													
17	01-23-82	6.6	140	84	100	0.45	0.14	0.44	0.26	0.16	0.02	6.8	10	73
18	Priority pollutants													
19	02-19-82	7.3	67	60	145	0.27	0.14	0.38	0.24	0.19	0.06	4.5	10	61
20	No sample													
21	03-21-82	6.9	110	30	94	0.02	0.05	0.63	0.35	0.45	0.15	5.2	13	75
22	Discrete samples--refer to table													
23	03-31-82	6.8	140	75	93	0.33	0.63	1.7	1.5	0.97	0.71	13	17	84
24	No sample													
25	Discrete samples--refer to table													
26	Discrete samples--refer to table													
27	Discrete samples--refer to table													

*Field duplicates

Water Quality Data
Composite Samples Collected at the Strip Commercial (SC) Site

Storm number	Date collected	Fecal coliform (bacteria/100 ml)	Fecal strep (bacteria/100 ml)	BOD_5 (mg/L)	Total alkalinity (mg/L as $CaCO_3$)	SO_4 (mg/L)	Cl (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)
Base	06-11-81	-	-	5.6	100	33	15	36.0	5.44	19.80	6.1
Base*	06-17-81	-	-	>12.0	120	39	25	34.3	6.33	29.20	6.1
Base*	06-17-81	>2,000	>2,000	>12.0	110	40	24	35.2	6.62	30.70	6.3
1	No sample										
2	08-06-81	5,000	>20,000	22.0	39	11	4	23.2	2.20	2.90	2.4
3	08-08-81	44,000	44,000	7.5	29	5	1	15.4	1.26	1.12	1.6
4	08-12-81	55,000	27,000	17.0	22	14	3	25.8	2.51	1.90	1.8
5	No sample										
6	08-18-81	32,000	360,000	12.0	34	20	4	22.9	1.82	3.06	2.2
7	08-21-81	4,000	20,000	1.5	1	5	2	16.1	1.43	0.78	1.1
8	No sample										
9	09-16-81	17,000	70,000	2.6	31	4	1	14.0	1.47	0.52	1.4
10	Priority pollutants										
11	Discrete samples--refer to table										
12	10-27-81	1,000	34,000		30	6	1	20.7	1.62	0.84	1.4
13	No sample										
14	11-24-81	1,000	36,000	21	31	9	2	13.4	1.24	1.31	1.4
15	12-01-81	1,400	35,000	10	32	6	1	13.7	1.35	1.21	1.3
16	No sample										
17	01-23-82	1,400	22,000	4.7	44			20	2.6		
18	Priority pollutants										
19	02-19-82	165	11,000	5.3	28			27.0	3.1		
20	No sample										
21	03-21-82	2,200	>2,000,000	36	40						
22	Discrete samples--refer to table										
23	03-31-82	50,500	33,500	16	29						
24	No sample										
25	Discrete samples--refer to table										
26	Discrete samples--refer to table										
27	Discrete samples--refer to table										

*Field duplicate

Water Quality Data
Composite Samples Collected at the Strip Commercial (SC) Site

Storm number	Date collected	Cu (μg/L)			Zn (μg/L)			Cr (μg/L)			Se (μg/L)		
		Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
Base	06-11-81	<1			<5			2			<1		
Base*	06-17-81	5	<1	2	<5	<5	19	<1	<1	6	<1	<1	<0.5
Base*	06-17-81	4	<1	4	<5	<5	19	<1	2	5	<1	<1	<0.5
1	No sample												
2	08-06-81	28			237			4			<1		
3	08-08-81	46	14	6	101	<5	75	33	<1	15	<1	<1	<0.2
4	08-12-81	39			240			14			<1		
5	No sample												
6	08-18-81	24			131			3			<1		
7	08-21-81	18			115			2			<1		
8	No sample												
9	09-16-81	<1	<1		67	<5		2	1		<1	<1	
10	Priority pollutants												
11	Discrete samples--refer to table												
12	10-27-81	24			96			2					
13	No sample												
14	11-24-81	27			129			2					
15	12-01-81	61	23		106	32		3	1				
16	No sample												
17	01-23-82	38	40		170	26		10	2				
18	Priority pollutants												
19	02-19-82	32	9		223	15		7	4				
20	No sample												
21	03-21-82												
22	Discrete samples--refer to table												
23	03-31-82												
24	No sample												
25	Discrete samples--refer to table												
26	Discrete samples--refer to table												
27	Discrete samples--refer to table												

*Field duplicates

Water Quality Data
Composite Samples Collected at the Strip Commercial (SC) Site

Storm number	Date collected	Hg (µg/L) Total	Hg (µg/L) Dissolved	Hg (µg/L) Suspended	Ni (µg/L) Total	Ni (µg/L) Dissolved	Ni (µg/L) Suspended	Cd (µg/L) Total	Cd (µg/L) Dissolved	Cd (µg/L) Suspended	Pb (µg/L) Total	Pb (µg/L) Dissolved	Pb (µg/L) Suspended
Base	06-11-81	<0.2			<100			0.6			20		
Base*	06-17-81	<0.2	<0.2	<0.07	<100	<100	<25	0.6	0.5	<1.0	8	<1	8
Base*	06-17-81	<0.2	<0.2	<0.07	<100	<100	<25	0.7	0.3	<1.0	9	<1	6
1	No sample												
2	06-06-81	<0.2			<50			1.2			310		
3	08-08-81	<0.2	<0.2	<0.1	<50	<50	<10	0.8	0.2	0.4	150	6	100
4	08-12-81	<0.2			<50			1.5			340		
5	No sample												
6	08-18-81	0.2			<50			1.0			180		
7	08-21-81	<0.2			<50			0.6			230		
8	No sample												
9	09-16-81	<0.2	<0.2		<50	<50		1.0	1.9		140	5	
10	Priority pollutants												
11	Discrete samples--refer to table												
12	10-27-81	<0.2						0.5			190		
13	No sample												
14	11-24-81	<0.2						0.8			200		
15	12-01-81	<0.2	<0.2					0.5	0.2		210	8	
16	No sample												
17	01-23-82							0.8	0.1		260	6	
18	Priority pollutants												
19	02-19-82							1.1	0.2		335	2	
20	No sample												
21	03-21-82												
22	Discrete samples--refer to table												
23	03-31-82												
24	No sample												
25	Discrete samples--refer to table												
26	Discrete samples--refer to table												
27	Discrete samples--refer to table												

*Field duplicates

Water Quality Data
Composite Samples Collected at the Strip Commercial (SC) Site

Storm number	Date collected	Fe (µg/L)			Mn (µg/L)			Al (µg/L)		
		Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
Base	06-11-81	655			48					
Base*	06-17-81	253	<5	224	52	9	31			
Base*	06-17-81	252	<5	200	55	4	30			
1	No sample									
2	08-06-81	2860			114					
3	08-08-81	1370	7	1480	68	<5	57			
4	08-12-81	2880			145					
5	No sample									
6	08-18-81	1600			86					
7	08-21-81	1370			80			730		
8	No sample									
9	09-16-81	1350	92		66	<5				
10	Priority pollutants									
11	Discrete samples--refer to table									
12	10-27-81	1240			58			640		
13	No sample									
14	11-24-81	1380			72			590		
15	12-01-81	1260	37		68	15		850	<50	
16	No sample									
17	01-23-82	3500	38		130	11		1700	100	
18	Priority pollutants									
19	02-19-82	4240	27		196	17		2250	60	
20	No sample									
21	03-21-82									
22	Discrete samples--refer to table									
23	03-31-82									
24	No sample									
25	Discrete samples--refer to table									
26	Discrete samples--refer to table									
27	Discrete samples--refer to table									

*Field duplicates

Water Quality Data
Composite Samples Collected at the Residential 1 (R1) Site

Storm number	Date collected	pH	Conductivity (µmhos at 25°C)	TDS (mg/L)	TSS (mg/L)	NO_2+NO_3-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	DKN (mg/L)	TP (mg/L)	DP (mg/L)	SOC (mg/L)	TOC (mg/L)	COD (mg/L)
1	07-02-81	6.7	100	140	42	0.58	0.20	1.40	0.72	1.00	0.18	6.2	16.0	63
2	08-06-81	6.7	130	110	250	0.80	0.04	0.64	0.64	0.54	0.23	25.0	27.0	63
3	No sample													
4	No sample													
5	No sample													
6	No sample													
7	08-21-81	6.0	90	80	470	0.99	0.08	0.78	0.30	0.52	0.13	5.3	11.0	87
8	09-15-81	6.9	150	110	560	0.72	0.09	0.82	0.36	0.62	0.13	11.0	40.0	140
9	09-16-81	7.0	112	106	1100	0.09	0.14	1.40	0.22	0.84	0.06	5.1	5.9	10
10	Priority pollutants													
11	10-23-81	6.6	98	90	170	0.54	0.05	1.20	0.36	0.57	0.20	28.0	42.0	100
12	10-27-81	7.0	100	90	730	0.45	0.04	1.70	0.28	1.20	0.10	13.0	31.0	93
13	Discrete samples--refer to table													
14	11-24-81	6.9	93	90	180	0.76	0.12	1.0	0.60	0.55	0.19	17.0	41.0	110
15	Discrete samples--refer to table													
16	01-21-82	7.5	160	90	710	0.46	0.25	1.20	0.36	0.73	0.03	10.0	31.0	200
17	01-23-82	6.6	110	110	450	0.27	0.17	0.72	0.08	0.36	0.02	11.0	31.0	120
18	Priority pollutants													
19	02-09-82	7.2	79	180	1000	0.27	0.13	1.5	0.28	0.78	0.09	9.8	33.0	180
20	No sample													
21	Discrete samples--refer to table													
22	No sample													
23	No sample													
24	No sample													
25	No sample													
26	No sample													
27	Discrete samples--refer to table													

Water Quality Data
Composite Samples Collected at the Residential 1 (R1) Site

Storm number	Date collected	Fecal coliform (bacteria/100 ml)	Fecal strep (bacteria/100 ml)	BOD_5 (mg/L)	Total alkalinity (mg/L as $CaCO_3$)	SO_4 (mg/L)	Cl (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)
1	07-02-81	2,200	>2,000	12.9	20	17	1	35.7	4.61	0.48	2.7
2	08-06-81	>200,000	>20,000	16.0	32	13	3	17.2	2.20	1.60	6.1
3	No sample										
4	No sample										
5	No sample										
6	No sample										
7	08-21-81	23,000	280,000	4.8	37	12	1	21.7	3.21	0.44	4.3
8	09-15-81	260,000	440,000	12.0	45	12	<1	31.6	4.67	0.57	4.0
9	09-16-81	90,000	450,000	9.0	58	3.7	1	54.1	9.44	0.39	2.9
10	Priority pollutants										
11	10-23-81	13,000	46,000		37	10	3	16.9	1.97	1.34	9.4
12	10-27-81	20,000	160,000		56	4	2	36.7	5.41	0.65	5.9
13	Discrete samples--refer to table										
14	11-24-81	10,000	71,000	27	35	10	2	13.2	1.60	0.88	6.0
15	Discrete samples--refer to table										
16	01-21-82	650	84,000		59			35.0	6.2		
17	01-23-82	875	58,000	3.5	43			20.0	3.7		
18	Priority pollutants										
19	02-09-82	1,100	12,000	6.6	36			32.0	5.6		
20	No sample										
21	Discrete samples--refer to table										
22	No sample										
23	No sample										
24	No sample										
25	No sample										
26	No sample										
27	Discrete samples--refer to table										

Water Quality Data
Composite Samples Collected at the Residential 1 (R1) Site

Storm number	Date collected	Cu (µg/L)			Zn (µg/L)			Cr (µg/L)			Se (µg/L)		
		Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
1	07-02-81	48			337			5			<1		
2	08-06-81	38			218			13			<1		
3	No sample												
4	No sample												
5	No sample												
6	No sample												
7	08-21-81	28			302			6			<1		
8	09-15-81	58			434			17			<1		
9	09-16-81	92	<1		772	<5		13	2		<1	<1	
10	Priority pollutants												
11	10-23-81	22			191			4			<1		
12	10-27-81	67			536			8					
13	Discrete samples--refer to table												
14	11-24-81	27			131			2					
15	Discrete samples--refer to table												
16	01-21-82	93	10		600	36		270	6				
17	01-23-82	72	23		308	19		9	2				
18	Priority pollutants												
19	02-09-82	108	7		600	25		33	1				
20	No sample												
21	Discrete samples--refer to table												
22	No sample												
23	No sample												
24	No sample												
25	No sample												
26	No sample												
27	Discrete samples--refer to table												

Water Quality Data
Composite Samples Collected at the Residential 1 (R1) Site

Storm number	Date collected	Hg (µg/L)			Ni (µg/L)			Cd (µg/L)			Pb (µg/L)		
		Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
1	07-02-81	<0.2			<100			1.9			420		
2	08-06-81	<0.2			<50			1.2			180		
3	No sample												
4	No sample												
5	No sample												
6	No sample												
7	08-21-81	0.2			<50			0.8			300		
8	09-15-81	0.3			<50			1.2			470		
9	09-16-81	0.05	<0.2		<50	<50		2.7	0.2		750	2	
10	Priority pollutants												
11	10-23-81	<0.2			50			0.6			210		
12	10-27-81	0.4						2.6			800		
13	Discrete samples--refer to table												
14	11-24-81	0.2						0.6			170		
15	Discrete samples--refer to table												
16	01-21-82	0.2	<0.4					5.0	0.2		600	10	
17	01-23-82							1.0	0.4		280	6	
18	Priority pollutants												
19	02-09-82							3.0	0.3		560	1	
20	No sample												
21	Discrete samples--refer to table												
22	No sample												
23	No sample												
24	No sample												
25	No sample												
26	No sample												
27	Discrete samples--refer to table												

Water Quality Data
Composite Samples Collected at the Residential 1 (Rl) Site

Storm number	Date collected	Fe (µg/L)			Mn (µg/L)			Al (µg/L)		
		Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
1	07-02-81	2,720			841					
2	08-06-81	9,800			264					
3	No sample									
4	No sample									
5	No sample									
6	No sample									
7	08-21-81	11,000			480			5,860		
8	09-15-81	12,900			764					
9	09-16-81	17,200	245		1550	<5				
10	Priority pollutants									
11	10-23-81	3,600			244			2,460		
12	10-27-81	12,800			941			8,560		
13	Discrete samples--refer to table									
14	11-24-81	3,980			218			1,970		
15	Discrete samples--refer to table									
16	01-21-82	29,000	188		1260	112		10,000	<50	
17	01-23-82	19,000	110		570	25		7,400	160	
18	Priority pollutants									
19	02-09-82	39,000	22		1100	4				
20	No sample									
21	Discrete samples--refer to table									
22	No sample									
23	No sample									
24	No sample									
25	No sample									
26	No sample									
27	Discrete samples--refer to table									

Water Quality Data
Composite Samples Collected at the Residential 2 (R2) Site

Storm number	Date collected	pH	Conductivity (µmhos at 25°C)	TDS (mg/L)	TSS (mg/L)	NO_2+NO_3-N (mg/L)	NH_3-N (mg/L)	TKN (mg/L)	DKN (mg/L)	TP (mg/L)	DP (mg/L)	SOC (mg/L)	TOC (mg/L)	COD (mg/L)
1	07-02-81	7.1	70	52	800	0.41	0.14	0.32	0.32	0.14	0.05	5.0	8.7	35
2	08-06-81	6.4	160	100	23	0.67	0.03	0.94	0.46	0.37	0.24	5.1	6.1	46
3	No sample													
4	08-12-81	7.0	150	72	5	0.68	0.02	0.64	0.54	0.35	0.16	5.5	10.0	69
5	No sample													
6	No sample													
7	08-21-81	5.6	70	40	18	0.22	0.07	0.32	0.30	0.16	0.10	3.4	4.4	25
8	09-15-81	7.2	96	58	47	0.62	0.06	0.41	0.25	0.22	0.14	6.8	8.8	38
9	09-16-81	7.2	66	42	75	0.15	0.04	0.37	0.26	0.20	0.13	5.5	9.8	30
10	Priority pollutants													
11	Discrete samples--refer to table													
12	10-27-81	7.0	72	60	46	0.15	0.04	0.36	0.14	0.15	0.06	4.5	7.3	25
13	No sample													
14	No sample													
15	No sample													
16	No sample													
17	01-23-82	6.4	120	87	71	0.16	0.09	0.48	0.10	0.17	0.06	10.0	12.0	57
18	Priority pollutants													
19	02-09-82	6.9	63	70	150	0.20	0.05	0.46	0.18	0.40	0.31	5.0	11.0	53
20	No sample													
21	03-21-82	7.0	95	40	68	0.02	0.02	0.40	0.38	0.19	0.08			
22	Discrete samples--refer to table													
23	03-31-82	6.8				0.36	0.15	0.54	0.54	0.34	0.11	12.0	16.0	72
24	No sample													
25	No sample													
26	Discrete samples--refer to table													
27	Discrete samples--refer to table													

Water Quality Data
Composite Samples Collected at the Residential 2 (R2) Site

Storm number	Date collected	Fecal coliform (bacteria/100 ml)	Fecal strep (bacteria/100 ml)	BOD_5 (mg/L)	Total alkalinity (mg/L as $CaCO_3$)	SO_4 (mg/L)	Cl (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)
1	07-02-81	1,800	<2,000	9.9	50	6	<1	11.8	1.08	0.36	1.4
2	08-06-81	14,000	<20,000	16.0	38	8	9	19.4	1.80	2.30	2.4
3	No sample										
4	08-12-81	860,000	34,000	18.0	23	14	3	20.9	1.70	1.44	1.9
5	No sample										
6	No sample										
7	08-21-81	10,000	18,000	8.0	28	4	1	11.6	0.97	0.45	1.2
8	09-15-81	9,000	420,000	6.2	45	8	1	13.5	1.30	0.64	2.2
9	09-16-81	10,000	72,000	3.2	32	4	<1	12.6	1.44	0.34	2.8
10	Priority pollutants										
11	Discrete samples--refer to table										
12	10-27-81	4,000	45,000		37	4	<1	13.7	1.14	0.55	1.3
13	No sample										
14	No sample										
15	No sample										
16	No sample										
17	01-23-82	520	36,000	3.3	47			18	1.9		
18	Priority pollutants										
19	02-09-82	300	30,000	4.6	25			20.0	2.1		
20	No sample										
21	03-21-82	2,800	400,000		39						
22	Discrete samples--refer to table										
23	03-31-82	50,500	33,500	15							
24	No sample										
25	No sample										
26	Discrete samples--refer to table										
27	Discrete samples--refer to table										

Water Quality Data
Composite Samples Collected at the Residential 2 (R2) Site

Storm number	Date collected	Cu (µg/L)			Zn (µg/L)			Cr (µg/L)			Se (µg/L)		
		Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
1	07-02-81	<1			65			2			<1		
2	08-06-81	9			80			10			<1		
3	No sample												
4	08-12-81	37			166			9			<1		
5	No sample												
6	No sample												
7	08-21-81	9			30			3			<1		
8	09-15-81	21			43			4			<1		
9	09-16-81	12	12		51	10		11	1		<1	<1	
10	Priority pollutants												
11	Discrete samples--refer to table												
12	10-27-81	9			85			3					
13	No sample												
14	No sample												
15	No sample												
16	No sample												
17	01-23-82	36	9		106	18		4	<1				
18	Priority pollutants												
19	02-09-82	27	8		150	19		4	<1				
20	No sample												
21	03-21-82												
22	Discrete samples--refer to table												
23	03-31-82												
24	No sample												
25	No sample												
26	Discrete samples--refer to table												
27	Discrete samples--refer to table												

Water Quality Data
Composite Samples Collected at the Residential 2 (R2) Site

Storm number	Date collected	Hg (µg/L)			Ni (µg/L)			Cd (µg/L)			Pb (µg/L)		
		Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
1	07-02-81	<0.2			<100			0.6			96		
2	08-06-81	<0.2			<50			0.4			89		
3	No sample												
4	08-12-81	<0.2			<50			0.9			180		
5	No sample												
6	No sample												
7	08-21-81	<0.2			<50			0.2			57		
8	09-15-81	<0.2			<50			0.6			98		
9	09-16-81	<0.2	0.7		<50	<50		0.5	0.5		99	2	
10	Priority pollutants												
11	Discrete samples--refer to table												
12	10-27-81	<0.2						0.6			160		
13	No sample												
14	No sample												
15	No sample												
16	No sample												
17	01-23-82							0.7	<0.1		150	6	
18	Priority pollutants												
19	02-09-82							0.8	0.2		220	5	
20	No sample												
21	03-21-82												
22	Discrete samples--refer to table												
23	03-31-82												
24	No sample												
25	No sample												
26	Discrete samples--refer to table												
27	Discrete samples--refer to table												

Water Quality Data
Composite Samples Collected at the Residential 2 (R2) Site

Storm number	Date collected	Fe (µg/L)			Mn (µg/L)			Al (µg/L)		
		Total	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Dissolved	Suspended
1	07-02-81	379			58					
2	08-06-81	982			57					
3	No sample									
4	08-12-81	2320			104					
5	No sample									
6	No sample									
7	08-21-81	581			25			370		
8	09-15-81	1630			74					
9	09-16-81	2200	125		122	<5				
10	Priority pollutants									
11	Discrete samples--refer to table									
12	10-27-81	1260			64			760		
13	No sample									
14	No sample									
15	No sample									
16	No sample									
17	01-23-82	2900	82		110	11		1200	<50	
18	Priority pollutants									
19	02-09-82	5100	67		210	7		2600	60	
20	No sample									
21	03-21-82									
22	Discrete samples--refer to table									
23	03-31-82									
24	No sample									
25	No sample									
26	Discrete samples--refer to table									
27	Discrete samples--refer to table									

APPENDIX F

URBAN RUNOFF LOADS

LOADING RATES OF GENERAL WATER QUALITY PARAMETERS

Central Business District (CBD)

Storm	Total flow	TDS (g/ha/cm)	TSS (g/ha/cm)	NO_3 (g/ha/cm)	NH_3 (g/ha/cm)	TKN (g/ha/cm)	DKN (g/ha/cm)	TP (g/ha/cm)	DP (g/ha/cm)	SOC (g/ha/cm)	TOC (g/ha/cm)	COD (g/ha/cm)
2	60.952	2295.16	5,363.3	11.434	0.000	22.119	-	9.341	2.507	1185.54	1317.91	3514.91
3	16.402	0.00	1,361.7	0.000	0.000	0.000	-	0.000	0.000	0.00	0.00	394.17
5	0.332	0.00	7,428.2	1.054	0.269	0.000	-	1.820	0.000	0.00	0.00	1196.51
6	9.792	0.00	2,743.3	28.194	1.334	16.434	-	5.094	0.000	0.00	44.11	823.64
7	230.082	2580.43	2,949.1	23.105	3.779	15.464	-	5.643	1.451	265.92	315.75	2219.24
8	156.392	1977.50	1,548.2	17.249	0.370	11.991	-	3.056	0.603	286.46	378.74	1502.23
10	36.842	-	-	-	-	-	-	-	-	-	-	-
11	252.382	1820.64	3,654.2	16.299	6.788	14.616	-	5.085	0.725	192.74	294.92	1418.61
12	103.352	1449.39	4,386.3	8.114	3.236	7.963	-	4.207	0.285	103.48	230.55	695.83
13	60.672	283.36	2,950.1	13.686	4.111	10.802	-	5.518	0.493	19.59	77.04	1216.35
14	79.862	32.77	1,449.8	25.296	7.291	14.890	-	4.607	0.389	10.41	273.19	1776.60
15	247.812	1053.46	1,441.6	8.980	2.629	10.995	-	3.075	0.338	95.04	269.34	1247.87
17	227.892	3282.07	5,027.3	12.713	4.700	22.157	-	7.227	0.000	293.58	550.80	3294.72
18	337.662	1978.93	1,890.8	14.639	6.141	18.253	-	4.654	1.187	166.87	385.01	2103.60
19	213.092	-	-	-	-	-	-	-	-	-	-	-
20	88.272	1723.66	13,904.7	25.027	6.183	11.880	-	9.741	0.000	63.199	356.184	3695.04
21	191.122	456.09	910.8	7.142	1.666	5.023	-	1.494	-	-	312.802	900.88
22	15.832	-	-	-	-	-	-	-	-	-	-	-
23	45.422	2053.47	1,597.7	3.562	0.000	3.857	-	3.704	1.535	106.221	194.145	3891.12
24	12.542	0.00	3,689.5	0.000	0.000	0.000	-	1.222	-	-	0.000	1477.96
25	55.362	132.19	1,608.4	4.594	3.031	15.558	-	5.132	-	-	139.364	2027.87
27	186.562	-	-	-	-	-	-	-	-	-	-	-

Central Business District (CBD)

Storm	Total flow	Coliforms (10^6 Org./ha/cm x 100 ml) Fecal	Coliforms (10^6 Org./ha/cm x 100 ml) Strep	BOD (g/ha/cm)	Alk (g/ha/cm)	SO_4 (g/ha/cm)	Cl (g/ha/cm)	Ca (g/ha/cm)	Mg (g/ha/cm)	Na (g/ha/cm)	K (g/ha/cm)
2	60.952	-	-	716.659	1020.53	36.625	0.000	807.81	60.091	0.000	95.440
3	16.402	-	-	0.000	0.00	0.000	0.000	0.00	0.000	0.000	13.135
5	0.332	-	-	-	0.00	0.000	0.000	137.97	0.000	0.000	9.704
6	9.792	-	-	200.113	0.00	0.000	0.000	138.12	0.000	0.000	69.265
7	230.082	-	-	175.629	1389.59	295.457	0.000	920.95	89.786	2.333	84.298
8	156.392	-	-	271.636	659.71	307.243	14.451	467.60	50.872	0.000	56.487
10	36.842	-	-	-	-	-	-	-	-	-	-
11	252.382	-	-	209,195	1061.37	270.258	0.000	604.67	58.043	0.000	76.109
12	203.352	-	-	-	1798.92	95.601	0.000	956.44	107.832	0.000	92.319
13	60.672	-	-	156.170	148.47	0.000	0.000	473.77	32.644	0.000	47.425
14	79.862	-	-	317.391	142.88	56.111	0.000	145.68	0.000	0.000	49.598
15	247.812	-	-	353.678	648.96	121.507	0.000	289.04	16.104	0.000	59.556
17	227.892	-	-	526.441	1549.89	-	-	763.80	92.504	-	-
18	337.662	-	-	650.605	735.50	-	-	411.88	34.053	-	-
19	213.092	-	-	-	-	-	-	-	-	-	-
20	88.272	-	-	401.008	1231.94	-	-	2293.83	320.467	-	-
21	191.122	-	-	331.277	651.13	-	-	-	-	-	-
22	15.832	-	-	-	-	-	-	-	-	-	-
23	45.422	-	-	438.820	0.00	-	-	379.51	0.868	-	-
24	12.542	-	-	155.353	0.00	-	-	-	-	-	-
25	55.362	-	-	-	281.22	-	-	-	-	-	-
27	186.562	-	-	-	-	-	-	-	-	-	-

LOADING RATES OF GENERAL WATER QUALITY PARAMETERS

Residential Site (R1)

Storm	Total flow	TDS (g/ha/cm)	TSS (g/ha/cm)	NO_3 (g/ha/cm)	NH_3 (g/ha/cm)	TKN (g/ha/cm)	DKN (g/ha/cm)	TP (g/ha/cm)	DP (g/ha/cm)	SOC (g/ha/cm)	TOC (g/ha/cm)	COD (g/ha/cm)
1	60.070	299.19	89.76	1.239	0.427	2.991	1.538	2.137	0.384	13.250	34.193	134.64
2	14.300	226.87	515.62	1.649	0.082	1.320	1.319	1.113	0.474	51.687	55.687	129.94
7	110.420	362.62	2130.39	4.487	0.362	3.535	1.359	2.357	0.589	24.023	49.860	394.35
8	107.520	664.38	3382.28	4.348	0.543	4.952	2.174	3.744	0.785	66.438	241.591	845.57
9	121.030	792.32	8261.20	0.675	1.051	10.514	1.652	6.308	0.450	38.302	44.310	75.10
11	70.820	347.08	655.59	2.082	0.192	4.627	1.388	2.198	0.771	107.980	161.790	385.64
12	145.060	860.12	6976.56	4.300	0.382	16.246	2.675	11.468	0.955	124.240	296.265	888.79
13	19.740	831.05	5217.01	2.034	1.191	17.200	2.950	8.534	1.042	174.473	352.918	2380.93
14	37.350	389.97	779.94	3.293	0.519	4.330	2.599	2.383	0.823	73.661	177.653	476.63
15	134.060	588.50	1291.15	1.493	0.303	4.301	1.174	2.479	0.716	66.852	106.870	471.35
16	195.570	-	-	-	-	-	-	-	-	-	-	-
17	141.430	-	-	-	-	-	-	-	-	-	-	-
18	172.310	-	-	-	-	-	-	-	-	-	-	-
19	185.750	1784.26	9912.53	2.676	1.288	14.868	2.775	7.731	0.892	97.143	327.114	1784.26
21	134.840	617.47	2415.53	1.237	0.760	5.695	-	2.777	-	-	120.396	623.53
22	23.570	-	-	-	-	-	-	-	-	-	-	-
23	41.390	-	-	-	-	-	-	-	-	-	-	-
27	95.640	452.839	6176.84	1.946	0.203	34.633	-	9.958	-	-	155.812	1608.59

Residential Site (Rl)

Storm	Total flow	Coliforms (10^6 Org./ha/cm x 100 ml) Fecal	Strep	BOD (g/ha/cm)	Alk (g/ha/cm)	SO_4 (g/ha/cm)	Cl (g/ha/cm)	Ca (g/ha/cm)	Mg (g/ha/cm)	Na (g/ha/cm)	K (g/ha/cm)
1	60.070	4,702	4,274	27.568	42.472	36.330	2.137	76.294	9.852	1.025	5.770
2	14.300	412,496	41,250	33.000	65.999	26.812	6.187	35.475	4.537	3.299	12.581
7	110.420	104,253	1,296,166	21.757	167.711	54.392	4.532	98.360	14.550	1.994	19.490
8	107.520	1,570,344	2,657,505	72.477	271.790	72.477	6.039	190.857	28.205	3.442	24.159
9	121.030	675,916	3,379,582	67.592	435.591	27.787	7.510	406.301	70.896	2.928	21.779
11	70.820	50,134	177,396	127.262	142.688	38.564	11.569	65.174	7.597	5.167	36.250
12	145.060	191,139	1,529,109	-	535.188	38.227	19.113	350.739	51.703	6.212	56.385
13	19.740	237,908	745,791	302.971	263.162	45.311	23.819	246.959	33.168	9.618	29.230
14	37.350	43,330	307,643	116.991	151.655	43.330	8.660	57.196	6.932	3.813	25.998
15	134.060	35,319	382,575	71.557	188.431	9.192	16.829	79.698	10.389	3.861	25.035
16	195.570	-	-	-	-	-	-	-	-	-	-
17	141.430	-	-	-	-	-	-	-	-	-	-
18	172.310	-	-	-	-	-	-	-	-	-	-
19	185.750	10,904	118,950	65.423	356.851	-	-	31.720	55.510	-	-
21	134.840	106,249	-	71.351	275.428	-	-	-	-	-	-
22	23.570	-	-	-	-	-	-	-	-	-	-
23	41.390	-	-	-	-	-	-	-	-	-	-
27	95.640	527,204	-	-	401.587	-	-	-	-	-	-

LOADING RATES OF GENERAL WATER QUALITY PARAMETERS

Residential Site (R2)

Storm	Total flow	TDS (g/ha/cm)	TSS (g/ha/cm)	NO_3 (g/ha/cm)	NH_3 (g/ha/cm)	TKN (g/ha/cm)	DKN (g/ha/cm)	TP (g/ha/cm)	DP (g/ha/cm)	SOC (g/ha/cm)	TOC (g/ha/cm)	COD (g/ha/cm)
1	123.470	297.327	4574.25	2.344	0.800	1.829	1.839	0.800	0.285	28.589	49.745	200.12
2	19.880	215.621	49.59	1.444	0.064	2.026	0.991	0.797	0.517	10.997	13.153	99.19
4	57.280	361.657	25.12	3.415	0.100	3.214	2.712	1.758	0.803	27.627	50.230	346.59
7	151.320	178.192	80.19	0.980	0.311	1.425	1.336	0.712	0.445	15.146	19.601	111.37
8	152.210	303.214	245.71	3.241	0.313	2.143	1.306	1.150	0.731	35.549	46.005	198.66
9	118.340	243.871	435.48	0.870	0.232	2.148	1.509	1.161	0.754	31.936	56.903	174.19
10	20.690	-	-	-	-	-	-	-	-	-	-	-
11	114.660	229.763	146.79	2.150	0.590	1.340	0.739	0.948	0.510	25.718	40.718	141.91
12	101.170	472.048	361.90	1.180	0.314	2.832	1.101	1.180	0.472	35.404	57.432	196.69
14	42.080	-	-	-	-	-	-	-	-	-	-	-
17	226.290	827.976	675.70	1.522	0.856	4.568	0.951	1.617	0.571	95.170	114.204	542.47
18	314.930	-	-	-	-	-	-	-	-	-	-	-
19	216.680	644.472	1381.01	1.841	0.460	4.235	1.657	3.682	2.854	46.034	101.274	487.96
21	244.140	402.493	684.24	0.201	0.201	4.024	3.823	1.911	0.804	53.330	94.586	432.68
22	82.310	806.404	3626.22	5.563	3.567	9.516	-	5.786	-	-	345.347	1689.12
23	125.220	722.538	639.96	3.715	1.548	5.573	5.573	3.509	1.135	123.864	165.152	743.18
26	61.390	510.566	1145.22	2.869	0.744	9.363	-	3.394	-	-	90.910	644.46
27	133.630	308.139	350.35	2.335	0.835	5.360	-	1.732	-	-	84.552	366.76

Residential Site (R2)

		Coliforms (10^6 Org./ha/cm x 100 ml)		BOD	Alk	SO_4	Cl	Ca	Mg	Na	K
Storm	Total flow	Fecal	Strep	(g/ha/cm)	(g/ha/cm)	(g/ha/cm)	(g/ha/cm)	(g/ha/cm)	(g/ha/cm)	(g/ha/cm)	(g/ha/cm)
1	123.470	10,292	11,436	56.606	285.891	34.306	5.717	67.470	6.175	2.058	8.004
2	19,880	30,187	43,124	34.499	81.936	17.249	19.405	41.831	3.881	4.959	5.174
4	57.280	4,319,790	170,782	70.322	115.529	70.322	15.069	104.981	8.539	7.233	9.543
7	151.320	44,548	80,186	35.638	124.734	17.819	4.454	51.676	4.321	2.004	5.345
8	152.210	47,050	2,195,686	32.413	235.252	41.822	5.227	70.576	6.796	3.345	11.501
9	118.340	58,065	418,065	18.581	185.807	23.225	5.806	73.161	8.361	1.974	16.258
10	20.690	-	-	-	-	-	-	-	-	-	-
11	114.660	30,309	109,381	33.002	128.802	33.464	7.382	62.433	5.385	3.408	8.575
12	101.170	31,469.9	354,036	-	291.096	31.469	7.867	107.784	8.968	4.327	10.227
14	42.080	-	-	-	-	-	-	-	-	-	-
17	226.290	4,948.8	342,611	31.406	447.297	-	-	171.305	18.082	-	-
18	214.930	-	-	-	-	-	-	-	-	-	-
19	216.680	2,762.0	276,202	42.351	230.169	-	-	184.135	19.334	-	-
21	244.140	28,174.5	4,024,926	57.355	392.430	-	-	221.371	18.112	-	-
22	82.310	5,217.4	-	-	588.260	-	-	-	-	-	-
23	125.220	1,032.2	92,898	154.830	268.371	-	-	258.049	17.547	-	-
26	61.390	29,339.5	-	-	254.555	-	-	-	-	-	-
27	133.630	42,122.7	-	-	249.006	-	-	-	-	-	-

LOADING RATES OF GENERAL WATER QUALITY PARAMETERS

Strip Commercial Site (SC)

Storm	Total flow	TDS (g/ha/cm)	TSS (g/ha/cm)	NO_3 (g/ha/cm)	NH_3 (g/ha/cm)	TKN (g/ha/cm)	DKN (g/ha/cm)	TP (g/ha/cm)	DP (g/ha/cm)	SOC (g/ha/cm)	TOC (g/ha/cm)	COD (g/ha/cm)
2	194.666	1715.62	1,751.7	11.873	8.781	22.649	21.255	11.081	7.257	425.254	513.658	2043.14
4	330.526	1452.33	86.7	14.604	0.470	13.149	5.711	8.440	2.171	132.365	216.978	1910.03
7	905.276	1410.64	1,255.4	22.990	1.046	8.817	9.518	4.392	2.747	143.774	197.262	385.82
8	887.166	-	-	-	-	-	-	-	-	-	-	-
9	444.585	-	-	-	-	-	-	-	-	-	-	-
10	190.436	-	-	-	-	-	-	-	-	-	-	-
11	668.936	1093.16	830.5	8.792	6.286	13.960	8.138	4.389	1.940	233.781	302.219	1142.13
12	452.106	1465.82	1,083.3	4.480	4.343	12.699	7.472	3.267	0.808	133.074	163.269	581.23
14	278.375	-	-	-	-	-	-	-	-	-	-	-
17	754.316	2258.84	3,248.8	14.583	4.466	12.416	8.815	3.222	0.000	165.537	267.348	2280.78
18	943.076	-	-	-	-	-	-	-	-	-	-	-
19	836.846	1638.53	4,669.8	7.937	5.121	11.273	7.923	3.001	0.000	131.803	301.997	2000.94
21	644.456	435.23	2,610.1	0.000	1.373	17.603	8.195	12.299	3.166	120.022	346.568	2141.43
22	247.436	2042.98	22,759.7	5.733	12.254	49.442	-	31.481	-	-	378.976	8794.45
23	328.386	1369.42	2,386.3	4.916	18.121	47.831	41.700	24.934	19.041	289.403	373.632	1948.89
26	285.456	2341.93	4,722.73	8.055	19.910	41.449	-	24.560	-	-	420.319	2601.74
27	629.486	921.05	1,447.32	6.075	2.321	16.0058	-	4.568	-	-	320.376	1224.07

Strip Commercial Site (SC)

Storm	Total flow	Coliforms (10^6 Org./ha/cm x 100 ml) Fecal	Strep	BOD (g/ha/cm)	Alk (g/ha/cm)	SO_4 (g/ha/cm)	Cl (g/ha/cm)	Ca (g/ha/cm)	Mg (g/ha/cm)	Na (g/ha/cm)	K (g/ha/cm)
2	194.666	-	-	-	621.99	163.700	24.896	461.127	35.976	0.000	39.812
4	330.526	-	-	-	338.45	275.756	35.473	586.981	53.580	1.202	32.633
7	905.276	-	-	-	0.00	102.690	39.081	394.603	33.201	2.413	22.709
8	887.166	-	-	-	-	-	-	-	-	-	-
9	444.585	-	-	-	-	-	-	-	-	-	-
10	190.436	-	-	-	-	-	-	-	-	-	-
11	668.936	-	-	-	590.26	169.813	39.485	335.974	26.084	0.000	24.893
12	452.106	-	-	-	700.92	136.781	0.000	629.833	43.137	0.000	33.772
14	278.375	-	-	-	-	-	-	-	-	-	-
17	754.316	-	-	-	1184.68	-	-	582.508	77.986	-	-
18	943.076	-	-	-	-	-	-	-	-	-	-
19	836.846	-	-	-	827.70	-	-	900.772	102.967	-	-
21	644.456	-	-	-	912.54	-	-	590.446	49.820	-	-
22	247.436	-	-	-	1456.73	-	-	-	-	-	-
23	328.386	-	-	-	507.15	-	-	485.224	53.724	-	-
26	285.456	-	-	-	976.707	-	-	-	-	-	-
27	629.486	-	-	-	792.427	-	-	-	-	-	-

METAL LOADING RATES

Strip Commercial Site (SC)

(mg/hectare/cm)

Storm	Total flow	Cu		Zn		Cr		Se		Hg	
		Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
2	194.666	696.37	-	5,950.0	-	78.520	-	20.962	-	4.192	-
4	330.526	954.42	-	6,142.6	-	359.214	-	22.649	-	4.529	-
7	905.276	482.12	-	3,202.5	-	44.834	-	24.197	-	4.839	-
8	887.166	-	-	-	-	-	-	-	-	-	-
9	444.585	-	-	-	-	-	-	-	-	-	-
10	190.436	-	-	-	-	-	-	-	-	-	-
11	668.936	401.79	-	3,181.0	-	107.192	-	27.704	-	5.938	-
12	452.106	838.46	-	3,045.5	-	53.358	-	-	-	5.875	-
14	278.375	-	-	-	-	-	-	-	-	-	-
17	654.316	1,154.26	-	5,652.6	-	350.959	-	-	-	-	-
18	943.076	-	-	-	-	-	-	-	-	-	-
19	836.846	1,078.06	-	7,841.9	-	250.830	-	-	-	-	-
21	644.456	662.66	-	3,555.4	-	7.772	-	-	-	4.857	-
22	247.436	3,417.65	-	21,829.2	-	522.314	-	-	-	12.905	-
23	328.386	1,070.98	-	4,560.9	-	75.009	-	-	-	-	-
26	285.456	2,470.86	-	3,877.10	-	156.382	-	-	-	10.541	-
27	629.486	1,830.56	-	3,290.90	-	90.504	-	-	-	8.841	-

Strip Commercial Site (SC)

(mg/hectare/cm)

Storm	Total flow	Ni		Cd		Pb		Fe		Mn		Al	
		Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
2	194.666	908.90	-	28.454	-	7,800.1	-	70,857	-	2,685.1	-	-	-
4	330.526	1,043.88	-	37.870	-	8,909.3	-	71,845	-	3,610.4	-	-	-
7	905.276	1,175.33	-	16.116	-	6,415.6	-	37,022	-	2,177.8	-	-	-
8	887.166	-	-	-	-	-	-	-	-	-	-	-	-
9	444.585	-	-	-	-	-	-	-	-	-	-	-	-
10	190.436	-	-	-	-	-	-	-	-	-	-	-	-
11	668.936	1,331.70	-	28.373	-	5,538.9	-	24,756	-	1,436.7	-	-	-
12	452.106	-	-	13.813	-	6,077.6	-	37,731	-	1,675.1	-	-	-
14	278.375	-	-	-	-	-	-	-	-	-	-	-	-
17	754.316	-	-	24.247	-	8,746.0	-	109,850	-	4,023.1	-	-	-
18	943.076	-	-	-	-	-	-	-	-	-	-	-	-
19	836.846	-	-	37.601	-	11,819.3	-	130,866	-	6,208.0	-	-	-
21	644.456	-	-	22.357	-	5,608.9	-	60,606	-	2,728.6	-	-	-
22	246.436	-	-	136.138	-	60,301.0	-	429,949	-	22,962.4	-	-	-
23	328.386	-	-	19.798	-	8,877.4	-	76,543	-	3,989.1	-	-	-
26	285.456	-	-	35.087	-	8,701.54	-	98,550.8	-	3,819.88	-	-	-
27	629.486	-	-	20.886	-	3,563.02	-	57,954.3	-	2,565.41	-	-	-

METAL LOADING RATES

Central Business District Site (CBD)

(mg/hectare/cm)

Storm	Total flow	Cu		Zn		Cr		Se		Hg	
		Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
2	60.952	1592.63	-	14,937.4	-	2932.40	-	21.747	-	4.349	-
3	16.402	518.70	-	1,968.8	-	0.00	-	10.640	-	2.128	-
5	0.332	815.22	-	6,677.1	-	0.00	-	0.225	-	2.264	-
6	9.792	572.71	-	8,706.7	-	0.00	-	6.352	-	1.270	-
7	230.082	855.73	-	7,485.2	-	0.00	-	26.697	-	5.339	-
8	156.392	712.28	-	6,120.7	-	1459.55	-	21.882	-	4.376	-
10	36.842	-	-	-	-	-	-	-	-	-	-
11	252.382	811.98	-	7,647.5	-	0.00	-	37.520	-	7.504	-
12	203.352	444.41	-	7,600.5	-	0.00	-	-	-	7.843	-
13	60.672	512.50	-	6,592.5	-	0.00	-	-	-	7.460	-
14	79.862	564.88	-	5,389.2	-	0.00	-	-	-	4.955	-
15	247.812	571.27	-	4,410.2	-	0.00	-	-	-	7.073	-
17	227.892	1984.01	-	11,663.2	-	0.00	-	-	-	-	-
18	337.662	-	-	-	-	-	-	-	-	-	-
19	213.092	1152.04	-	7,410.9	-	0.00	-	-	-	-	-
20	88.272	2181.53	-	20,206.0	-	0.00	-	-	-	10.601	-
21	191.122	2540.84	-	3,461.0	-	0.00	-	-	-	6.449	-
22	15.832	-	-	-	-	-	-	-	-	-	-
23	45.422	958.32	-	6,398.5	-	0.00	-	-	-	-	-
24	12.542	1640.59	-	6,013.7	-	0.00	-	-	-	6.827	-
25	55.362	2683.36	-	6,772.2	-	0.00	-	-	-	3.511	-
27	186.562	-	-	-	-	-	-	-	-	-	-

Central Business District Site (CBD)

(mg/hectare/cm)

Storm	Total flow	Ni		Cd		Pb		Fe		Mn		Al	
		Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
2	60.952	510.83	-	42.292	-	7,795.0	-	162,390	-	5,883.5	-	-	-
3	16.402	0.00	-	11.689	-	1,890.6	-	67,446	-	1,763.7	-	-	-
5	0.332	0.00	-	14.638	-	4,769.9	-	111,469	-	3,470.8	-	-	-
6	9.792	0.00	-	21.060	-	4,509.7	-	129,290	-	3,647.9	-	-	-
7	230.082	1147.35	-	17.750	-	3,787.5	-	98,632	-	3,439.0	-	-	-
8	156.392	868.03	-	16.828	-	2,962.8	-	51,643	-	2,059.0	-	-	-
10	36.842	-	-	-	-	-	-	-	-	-	-	-	-
11	252.382	1635.81	-	28,345	-	3,574.5	-	84,737	-	2,620.9	-	-	-
12	203.352	-	-	34.986	-	5,170.7	-	122,385	-	4,062.4	-	-	-
13	60.672	-	-	15.208	-	3,016.4	-	134,955	-	3,520.2	-	-	-
14	79.862	-	-	14.838	-	1,980.1	-	63,986	-	1,955.6	-	-	-
15	247.812	-	-	15.608	-	2,388.8	-	45,709	-	1,530.0	-	-	-
17	227.892	-	-	48.774	-	6,987.9	-	238,873	-	7,630.0	-	-	-
18	337.662	-	-	-	-	-	-	-	-	-	-	-	-
19	213.092	-	-	35.702	-	3,394.5	-	87.933	-	2,838.1	-	-	-
20	88.272	-	-	135.336	-	15,395.2	-	394,479	-	20,266.0	-	-	-
21	191.122	-	-	18.767	-	1,462.7	-	50,579	-	1,264.1	-	-	-
22	15.832	-	-	-	-	-	-	-	-	-	-	-	-
23	45.422	-	-	9.671	-	4,155.4	-	79,113	-	3,897.7	-	-	-
24	12.542	-	-	30.132	-	6,098.2	-	98,640	-	2,174.5	-	-	-
25	55.362	-	-	14.118	-	3,694.7	-	69,309	-	3,086.4	-	-	-
27	186.562	-	-	-	-	-	-	-	-	-	-	-	-

METAL LOADING RATES

Residential Site (Rl)

(mg/hectare/cm)

Storm	Total flow	Cu		Zn		Cr		Se		Hg	
		Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
1	60.070	102.58	-	720.20	-	10.685	-	2.137	-	0.427	-
2	14.300	78.37	-	449.62	-	26.812	-	2.062	-	0.412	-
7	110.420	126.92	-	1368.89	-	27.196	-	4.532	-	0.906	-
8	107.520	350.31	-	2621.27	-	102.676	-	6.039	-	1.811	-
9	121.030	690.94	7.510	5797.86	37,551	97.632	15,020	7.510	7,510	3.755	1.502
11	70.820	84.84	-	736.58	-	15.426	-	3.856	-	0.771	-
12	145.060	640.31	-	5122.52	-	76.455	-	-	-	3.822	-
13	19.740	501.78	-	5346.37	-	76.516	-	4.788	-	5.766	-
14	37.350	116.99	-	567.62	-	8.666	-	-	-	0.866	-
15	134.060	156.96	-	967.45	-	43.032	-	-	-	1.675	-
16	195.570	-	-	-	-	-	-	-	-	-	-
17	141.430	-	-	-	-	-	-	-	-	-	-
18	172.310	-	-	-	-	-	-	-	-	-	-
19	185.750	1070.55	69.387	5947.52	247,813	327.114	9,912	-	-	-	-
21	134.840	502.70	-	1873.17	-	31.019	-	-	-	1.752	-
22	23.570	-	-	-	-	-	-	-	-	-	-
23	41.390	-	-	-	-	-	-	-	-	-	-
27	95.640	1444.51	-	2063.51	-	251.826	-	-	-	2.812	-

Residential Site (R1)

(mg/hectare/cm)

Storm	Total flow	Ni		Cd		Pb		Fe		Mn		Al	
		Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
1	60.070	213.709	-	4.060	-	897.58	-	5,813	-	1,797.3	-	-	-
2	14.300	103.124	-	2.475	-	371.25	-	20,212	-	544/5	-	-	-
7	110.420	226.637	-	3.626	-	1359.82	-	49,860	-	2,175.7	-	26,562	-
8	107.520	301.989	-	7.274	-	2838.70	-	77,913	-	4,614.4	-	-	-
9	121.030	375.509	375,509	20.277	1.502	5632.64	15.020	129,175	1839.99	11,640.8	37.550	-	-
11	70.820	192.822	-	2.313	-	809.85	-	13,883	-	941.0	-	9,487	-
12	145.060	-	-	24.848	-	7645.55	-	122,329	-	8,993.1	-	81,807	-
13	19.740	239.414	-	17.231	-	4580.78	-	81,190	-	5,653.6	-	48,860	-
14	37.350	-	-	2.599	-	736.61	-	17,245	-	944.6	-	8,536	-
15	134.060	-	-	3,406	-	1188.24	-	33,160	-	1,662.2	-	35,290	-
16	195.570	-	-	3.406	-	-	-	-	-	-	-	-	-
17	141.430	-	-	-	-	-	-	-	-	-	-	-	-
18	172.310	-	-	-	-	-	-	-	-	-	-	-	-
19	185.750	-	-	29.737	2.973	5551.02	9.912	386,589	218.08	10,903.8	37.650	406,414	495,627
21	134.840	-	-	6.492	-	1701.98	-	73,345	-	3,125.5	-	87,880	-
22	23.570	-	-	-	-	-	-	-	-	-	-	-	-
23	41.390	-	-	-	-	-	-	-	-	-	-	-	-
27	95.640	-	-	21.031	-	4536.93	-	76,044.1	-	2,695.37	-	184,684	-

METAL LOADING RATES

Residential Site (R2)

(mg/hectare/cm)

Storm	Total flow	Cu		Zn		Cr		Se		Hg	
		Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
1	123.470	5.718	-	371.66	-	11.436	-	5.717	-	1.143	-
2	19.880	19.406	-	172.50	-	21.562	-	2.156	-	0.431	-
4	57.280	185.851	-	833.82	-	45.207	-	5.023	-	1.004	-
7	151.320	40.093	-	133.64	-	13.364	-	4.454	-	0.890	-
8	152.210	109.784	-	244.80	-	20.911	-	5.227	-	1.045	-
9	118.340	69.677	69.677	296.13	58.065	63.871	5.806	5.806	5.806	1.161	4.064
10	20.690	-	-	-	-	-	-	-	-	-	-
11	114.660	119.884	-	485.50	-	7.370	-	5.081	-	1.016	-
12	101.170	70.807	-	668.73	-	23.602	-	-	-	1.573	-
14	42.080	-	-	-	-	-	-	-	-	-	-
17	226.290	342.611	85.653	1008.80	171.305	38.068	9.517	-	-	-	-
18	214.930	-	-	-	-	-	-	-	-	-	-
19	216.680	248.582	73.654	1381.01	174.928	36.827	9.206	-	-	-	-
21	244.140	402.493	201.246	1006.23	301.869	140.872	10.062	-	-	2.012	2.012
22	82.310	888.739	-	4052.40	-	106.062	-	-	-	2.796	-
23	125.220	412.879	412.879	1238.64	619.318	20.644	10.322	-	-	-	-
26	61.390	272.737	-	1254.62	-	50.410	-	-	-	1.265	-
27	133.630	418.885	-	701.95	-	17.564	-	-	-	1.675	-

Residential Site (R2)

(mg/hectare/cm)

Storm	Total flow	Ni		Cd		Pb		Fe		Mn		Al	
		Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
1	123.470	571.782	-	3.430	-	548.91	-	2,167.1	-	331.63	-	-	-
2	19.880	107.811	-	0.862	-	191.90	-	2,117.4	-	122.90	-	-	-
4	57.280	251.151	-	4,520	-	904.14	-	11,653.4	-	522.39	-	-	-
7	151.320	222.740	-	0.891	-	253.92	-	2,588.2	-	111.37	-	1,648.3	-
8	152.210	261.391	-	3.136	-	512.33	-	8,521.4	-	386.86	-	-	-
9	118.340	290.323	290.323	2.903	2.903	574.84	11.613	12,774.2	725.807	708.39	29.032	-	-
10	20.690	-	-	-	-	-	-	-	-	-	-	-	-
11	114.660	254.073	-	2.099	-	586.07	-	4,230.5	-	223.65	-	1,834.6	-
12	101.170	-	-	4.720	-	1258.79	-	9,913.0	-	503.52	-	5,979.3	-
14	42.080	-	-	-	-	-	-	-	-	-	-	-	-
17	226.290	-	-	6.661	0.951	1427.54	57.102	27,599.2	780.391	1046.87	95.170	11,420.4	475.85
18	214.930	-	-	-	-	-	-	-	-	-	-	-	-
19	216.680	-	-	7.365	1.841	2025.48	46.034	46,954.4	616.852	1933.42	64.447	23,937.5	552.40
21	244.140	-	-	5.031	1.006	1277.91	201.246	18,112.2	301.869	1106.85	100.623	12,074.8	1006.23
22	82.310	-	-	19.663	-	6921.54	-	61,606.5	-	4390.88	-	55,905.1	-
23	125.220	-	-	5.161	-	1754.73	103.220	20,643.9	412.897	1548.30	722.538	13,418.6	1032.20
26	61.390	-	-	6.997	-	1771.56	-	25,367.8	-	1423.08	-	18,045.3	-
27	133.630	-	-	4.995	-	752.71	-	16,588.6	-	627.43	-	10,425.9	-

APPENDIX G

PRIORITY POLLUTANT DATA

NURP Priority Pollutant Data for Knoxville, Tennessee

(values in μg/L)

I. **PESTICIDES**	CBD 10/2/81	CBD 2/3/82	R1 10/2/81	R1 2/3/82	R2 10/2/81	R2 2/3/82	SC 10/2/81	SC 2/3/82	Storet code
1. Acrolein	WD-F	WD-F	WD-F	WD-F	WD-F	WD-F	WD-F	WD-F	34210
2. Aldrin	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	39330
3. α-Hexachlorocyclohexane	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	39337
4. β-Hexachlorocyclohexane	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	39338
5. γ-Hexachlorocyclohexane (Lindane)	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	39340
6. δ-Hexachlorocyclohexane	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	34259
7. Chlordane	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	39350
8. DDD	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	39310
9. DDE	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	39320
10. DDT	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	39300
11. Dieldrin	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	39380
12. α-Endosulfan	WD-C	WD-C	WD-C	WD-C	WD-C	WD-C	WD-C	WD-C	34361
13. β-Endosulfan	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	34356
14. Endosulfan sulfate	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	34351
15. Endrin	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	39390
16. Endrin aldehyde	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	34366
17. Heptachlor	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	39410
18. Heptachlor epoxide	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	39420
19. Isophorone	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34408
20. TCDD	(not analyzed)		(not analyzed)		(not analyzed)		(not analyzed)		
21. Toxaphene	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	39400

NURP Priority Pollutant Data
for Knoxville, Tennessee

(Continued)

(values in μg/L)

	CBD		R1		R2		SC		Storet code
	10/2/81	2/3/82	10/2/81	2/3/82	10/2/81	2/3/82	10/2/81	2/3/82	
II. METALS AND INORGANICS									
22. Antimony	2 u	2 u	2 u	2 u	2 u	2 u	2 u	2 u	01097
23. Arsenic	4	1	5	1	3	1 u	3	1 u	01002
24. Asbestos	(not analyzed)		(not analyzed)		(not analyzed)		(not analyzed)		
25. Beryllium	0.5 u	0.5 u	0.5 u	2.1	0.5 u	0.5 u	0.5 u	0.5 u	01012
26. Cadmium	0.8	0.6	2.0	1.7	0.8	0.4	1.1	0.4	01027
27. Chromium	20	6	5	11	3.1	12	2	1	01034
28. Copper	33	22	51	32	22	5	18	13	01042
29. Cyanides	20 u	20 u	20 u	20 u	20 u	20 u	20 u	20 u	00720
30. Lead	84	99	460	100	240	31	220	100	01051
31. Mercury	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u	0.2 u	71900
32. Nickel	50 u	4	50 u	24	50 u	2	50 u	1	01067
33. Selenium	1 u	1 u	1 u	1 u	1 u	1 u	1 u	1 u	01147
34. Silver	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	01077
35. Thallium	50 u	50 u	50 u	50 u	50 u	50 u	50 u	50 u	01059
36. Zinc	249	180	386	160	375	41	192	66	01092
III. PCB AND RELATED COMPOUNDS									
37. PCB-1016	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	34671
38. PCB-1221	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	39488
39. PCB-1232	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	39492
40. PCB-1242	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	39496
41. PCB-1248	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	39500
42. PCB-1254	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	39504
43. PCB-1260	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	0.1 u	39508
44. 2-Chloronaphthalene	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34581

NURP Priority Pollutant Data
for Knoxville, Tennessee

(Continued)

(values in ug/L)

IV. HALOGENATED ALIPHATICS	CBD		R1		R2		SC		Storet code
	10/2/81	2/3/82	10/2/81	2/3/82	10/2/81	2/3/82	10/2/81	2/3/82	
45. Methane, bromo-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34413
46. Methane, chloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34418
47. Methane, dichloro-	WD-B	10 u	WD-B	10 u	10 u	10 u	10 u	10 u	34423
48. Methane, chlorodibromo-	10 u	10 u	10 u	10 u	10 u	10 u	WD-B	10 u	32105
49. Methane, dichlorobromo-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	32101
50. Methane, tribromo-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	32104
51. Methane, trichloro- (chloroform)	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	32106
52. Methane, tetrachloro- (carbon t)	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	32102
53. Methane, trichlorofluoro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34488
54. Methane, dichlorodifluoro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34668
55. Ethane, chloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34311
56. Ethane, 1,1-dichloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34496
57. Ethane, 1,2-dichloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34531
58. Ethane, 1,1,1-trichloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34506
59. Ethane, 1,1,2-trichloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34511
60. Ethane, 1,1,2,2-tetrachloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34516
61. Ethane, hexachloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34396
62. Ethene, chloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	39175
63. Ethene, 1,1-dichloro-	WD-C	WD-C	WD-C	WD-C	WD-C	WD-C	WD-C	WD-C	34501
64. Ethene, 1,2-trans-dichloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34546
65. Ethene, trichloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	39180
66. Ethene, tetrachloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34475
67. Propane, 1,2-dichloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34541
68. Propene, 1,3-dichloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	77161
69. Butadiene, hexachloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34391
70. Cyclopentadiene, hexachloro-	WD-G	WD-G	WD-G	WD-G	WD-G	WD-G	WD-G	WD-G	34386

NURP Priority Pollutant Data
for Knoxville, Tennessee

(Continued)

(values in μg/L)

	CBD		R1		R2		SC		Storet
	10/2/81	2/3/82	10/2/81	2/3/82	10/2/81	2/3/82	10/2/81	2/3/82	code
V. ETHERS									
71. Ether, bis(choromethyl)	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34268
72. Ether, bis(2-chloroethyl)	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34273
73. Ether, bis(2-chloroisopropyl)	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34283
74. Ether, 2-chloroethyl vinyl	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34576
75. Ether, 4-bromophenyl phenyl	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34636
76. Ether, 4-chlorophenyl phenyl	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34641
77. Bis(2-chloroethoxy) methane	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34278
VI. MONOCYCLIC AROMATICS (EXCLUDING PHENOLS, CRESOLS, PHTHALATES)									
78. Benzene	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34030
79. Benzene, chloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34301
80. Benzene, 1,2-dishloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34536
81. Benzene, 1,3-dichloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34566
82. Benzene, 1,4-dichloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34571
83. Benzene, 1,2,4-trichloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34551
84. Benzene, hexachloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	39700
85. Benzene, ethyl-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34371
86. Benzene, nitro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34447
87. Toluene	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34010
88. Toluene, 2,4-dinitro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34611
89. Toluene, 2,6-dinitro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34626

NURP Priority Pollutant Data
for Knoxville, Tennessee

(Continued)

(values in ug/L)

		CBD		R1		R2		SC		
		10/2/81	2/3/82	10/2/81	2/3/82	10/2/81	2/3/82	10/2/81	2/3/82	Storet code
VII.	PHENOLS AND CRESOLS									
90.	Phenol	WD-E	WD-E	WD-E	WD-E	WD-E	WD-E	WD-E	WD-E	34694
91.	Phenol, 2-chloro-	25 u	25 u	25 u	25 u	25 u	25 u	25 u	25 u	34586
92.	Phenol, 2,4-dichloro-	25 u	25 u	25 u	25 u	25 u	25 u	25 u	25 u	34601
93.	Phenol, 2,4,6-trichloro-	25 u	25 u	25 u	25 u	25 u	25 u	25 u	25 u	34621
94.	Phenol, pentachloro-	25 u	25 u	25 u	25 u	25 u	25 u	25 u	25 u	39032
95.	Phenol, 2-nitro	25 u	25 u	25 u	25 u	25 u	25 u	25 u	25 u	34591
96.	Phenol, 4-nitro	25 u	25 u	25 u	25 u	25 u	25 u	25 u	25 u	34646
97.	Phenol, 2,4-dinitro-	250 u	250 u	250 u	250 u	250 u	250 u	250 u	250 u	34616
98.	Phenol, 2,4-dimethyl-	25 u	WD-E	25 u	WD-E	25 u	WD-E	25 u	WD-E	34606
99.	m-Cresol, p-chloro-	25 u	25 u	25 u	25 u	25 u	25 u	25 u	25 u	34452
100.	o-Cresol, 4,6-dinitro-	250 u	250 u	250 u	250 u	250 u	250 u	250 u	250 u	34657
VIII.	PHTHALATE ESTERS									
101.	Phthalate, dimethyl	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34341
102.	Phthalate, diethyl	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34336
103.	Phthalate, di-n-butyl	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	39110
104.	Phthalate, di-n-octyl	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34596
105.	Phthalate, bis(2-ethylhexyl)	11	10 u	10 u	10 u	10 u	10 u	10 u	10 u	39100
106.	Ththalate, butyl benzyl	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34292

NURP Priority Pollutant Data
for Knoxville, Tennessee

(Continued)

(values in $\mu g/L$)

		CBD		R1		R2		SC		Storet
IX.	POLYCYCLIC AROMATIC HYDROCARBONS	10/2/81	2/3/82	10/2/81	2/3/82	10/2/81	2/3/82	10/2/81	2/3/82	code
107.	Acenaphthene	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34205
108.	Acenaphthylene	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34200
109.	Anthracene	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34220
110.	Benzo(a)anthracene	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34526
111.	Benzo(b)fluoranthene	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34230
112.	Benzo(k)fluoranthene	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34242
113.	Benzo(g,h,i)perylene	25 u	25 u	25 u	25 u	25 u	25 u	25 u	25 u	34521
114.	Benzo(a)pyrene	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34247
115.	Chrysene	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34320
116	Dibenzo(a,h)anthracene	25 u	25 u	25 u	25 u	25 u	25 u	25 u	25 u	34556
117.	Fluoranthene	10 u	10 u	10 u	10 u	11	10 u	10 u	10 u	34376
118.	Fluorene	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34381
119.	Indeno(1,2,3-c,d)pyrene	25 u	25 u	25 u	25 u	25 u	25 u	25 u	25 u	34403
120.	Naphthalene	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34696
121.	Phenanthrene	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34461
122.	Pyrene	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34469
X.	NITROSAMINES AND OTHER NITROGEN-CONTAINING COMPOUNDS									
123.	Nitrosamine, dimethyl	WD-G	WD-G	WD-G	WD-G	WD-G	WD-G	WD-G	WD-G	34438
124.	Nitrosamine, diphenyl	WD-G	WD-G	WD-G	WD-G	WD-G	WD-G	WD-G	WD-G	34433
125.	Nitrosamine, di-n-propyl	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34428
126.	Benzidine	WD-G	WD-G	WD-G	WD-G	WD-G	WD-G	WD-G	WD-G	39120
127.	Benzidine, 3,3'-dichloro-	10 u	10 u	10 u	10 u	10 u	10 u	10 u	10 u	34336
128.	Hydrazine, 1,2-diphenyl-	WD-G	WD-G	WD-G	WD-G	WD-G	WD-G	WD-G	WD-G	34346
129.	Acrylonitrile	WD-F	WD-F	WD-F	WD-F	WD-F	WD-F	WD-F	WD-F	34215

Quality Control Codes for Withdrawn Data Points

Code	Explanation
WD-B	Contamination evidenced in blank or other source
WD-C	Unacceptably low performance evaluation result
WD-E	Unacceptable spike recovery result
WD-F	Holding time violation
WD-G	Analytical methodology inappropriate

Storet Remark Codes[1]

Code	
u	Indicates material was analyzed for but not detected.

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[1] Storet Remark Codes from Water Quality Control Information System (Storet) Handbook.

APPENDIX H

WET AND DRY PRECIPITATION QUALITY DATA

Atmospheric Deposition Data
Wetfall Samples Collected at the Central Business District (CBD) Site

Storm number	Date collected	Volume (ml)	pH	Conductivity (μmhos at 25°C)	TDS (mg/L)	TSS (mg/L)	NO_3-N (mg/L)	TKN (mg/L)	TOC (mg/L)	COD (mg/L)	TP (mg/L)
1	07-02-81	500	4.0	32	IS	4	0.28	0.50	3.2	8	<0.01
2	08-06-81	300	4.4	16	23	<1	1.45	0.33	4.7	16	0.04
3	No sample										
4	No sample										
5	08-16-81	225	4.1	27	<5	<1	0.75	1.30	10.5	63	0.03
6	08-18-81	145	4.1	33	<5	<1	1.25	1.58	11.6	63	<0.01
7	08-21-81	985	4.1	28	5.1	0.5	0.2	0.16	6.7	18	<0.01
8	09-15-81	740	3.8	62	20.3	1.6	0.36	0.40	4.6	11	0.01
9	09-16-81	670	5.4	7	0.0	1.5	0.11	0.26	3.4	5	<0.01
10	10-02-81	220	5.3	34	40.9	22.7	0.68	1.13	14.1	44	0.03
11	10-23-81	780	4.2	18	8	0.0	0.25	0.40	3.8	6	0.01
12	10-27-81	595	4.4	8	5.0	0.7	0.08	0.12	1.7	7	<0.01
13	11-20-81	350	4.2	18	9.1	0.5	0.20	0.40	4.0	11	0.01
14	11-24-81	370	4.4	32	9.0	0.4	0.52	0.35	4.9	8	0.01
15	12-01-81	820	4.3	14	16.8	10.2	0.10	0.08	2.0	<1	<0.01
16	No sample										
17	01-23-82	710	4.0	26	4.7	4.1	0.20	0.26	2.2	4	<0.01
18	02-03-82	1015	4.5	8	7.6	0.5	0.07	0.11	1.1	3	<0.01
19	02-09-82	720	3.8	27	8.7	0.0	0.18	0.34			0.01
20	03-05-82	355	4.6	17	33.3	8.2	0.35	0.33	5.6	15	<0.01
21	03-21-82	680	4.5	8	7.2	1.0	0.10	0.24	2.0	3	0.03
22	No sample										
23	03-31-82										
24	04-01-82	185	5.4	13	31.3	4.1	0.75	0.22	3.8	IS	0.06

IS = Insufficient sample

Atmospheric Deposition Data
Wetfall Samples Collected at the Central Business District (CBD) Site

Storm number	Date collected	SO_4 (mg/L)	Cl (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cu (total, µg/L)	Zn (total, µg/L)	Cr (total, µg/L)	Se (total, µg/L)	Hg (total, µg/L)
1	07-02-81	2.8	<0.1	0.32	0.04	<0.05	0.04	64	14	4	<1	<0.2
2	08-06-81	3.6	0.4	1.09	0.169	0.42	0.15	151	47	38	<1	20
3	No sample											
4	No sample											
5	08-16-81	7.0	0.5	1.50	0.255	1.48	0.25	75	55	8	<1	<0.2
6	08-18-81	12.9	0.8	2.42	0.425	4.13	0.50	121	104	21	<1	<0.2
7	08-21-81	2.1	0.1	0.33	0.060	<0.05	0.04	21	<5	<1	<1	<4.2
8	09-15-81	5.3	0.2	0.45	0.080	0.10	0.06	27	<5	2	<1	1.6
9	09-16-81	1.3	0.3	0.28	0.058	0.09	0.07	31	<5	18	<1	<0.2
10	10-02-81	6.4	0.68	4.10	0.66	0.77	0.38	85	108	5	<1	<0.2
11	10-23-81	2.0	0.3	0.28	0.071	0.24	0.06	14	314	3		<0.2
12	10-27-81	1.0	0.2	0.12	0.026	0.12	0.11	14	33	<1		<0.2
13	11-20-81	2.9	0.38	0.55	0.086	0.26	0.12	35	49	<1		<0.2
14	11-24-81	3.0	0.16	0.30	0.045	0.19	0.07	13	26	<1		<0.2
15	12-01-81	1.9	0.23	0.33	0.042	0.24	0.04	5	29	<1		<0.2
16	No sample											
17	01-23-82			0.45	0.07			44	120	<1		<0.2
18	02-03-82			1.40	0.04			9	11	<1		<0.2
19	02-09-82			0.21	0.05			130	30	<1		<0.2
20	03-05-82			1.08	0.18			111	95	<1		<0.2
21	03-21-82											
22	No sample											
23	03-31-82											
24	04-01-82											

Atmospheric Deposition Data
Wetfall Samples Collected at the Central Business District (CBD) Site

Storm number	Date collected	Ni (total, µg/L)	Cd (total, µg/L)	Pb (total, µg/L)	Fe (total, µg/L)	Mn (total, µg/L)	Al (total, µg/L)
1	07-02-81	<100	0.4	10	32	<5	
2	08-06-81	<50	2.0	36	222	<5	
3	No sample						
4	No sample						
5	08-16-81	<50	7.5	10	40	<5	
6	08-18-81	<50	4.6	33	158	<5	
7	08-21-81	<50	0.8	6	24	<5	
8	09-15-81	<50	0.6	20	70	<5	
9	09-16-81	<50	0.3	7	56	<5	
10	10-02-81	<50	0.8	23	746	18	
11	10-23-81		0.8	12	69	<5	50
12	10-27-81		1.0	10	42	7	<50
13	11-20-81		0.3	17	102	<5	92
14	11-24-81		0.1	23	54	<5	<50
15	12-01-81		0.2	15	78	<5	<70
16	No sample						
17	01-23-82		0.5	12	84	<5	<50
18	02-03-82		0.2	9	56	<5	<50
19	02-09-82		0.3	12	102	7	80
20	03-05-82		0.9	23	155	14	167
21	03-21-82						
22	No sample						
23	03-31-82						
24	04-01-82						

Atmospheric Deposition Data
Wetfall Samples Collected at the Strip Commercial (SC) Site

Storm number	Date collected	Volume (ml)	pH	Conductivity (µmhos at 25°C)	TDS (mg/L)	TSS (mg/L)	NO_3-N (mg/L)	TKN (mg/L)	TOC (mg/L)	COD (mg/L)	TP (mg/L)
1	07-02-81	600	4.2	23	IS	<1	0.15	0.20	3.7	8	0.01
2	08-06-81	300	4.3	18	<5	<1	0.7	0.40	3.3	13	0.05
3	08-08-81	350	4.4	20	17	3	0.6	0.31	7.5	18	0.03
4	08-12-81	400	3.8	76	12.5	2.5	2.8	0.67	23	88	<0.01
5	No sample										
6	08-18-81	140	4.8	28	<5	<1	0.87	1.57	43.5	217.4	0.04
7	08-21-81	940	4.1	27	8.5	0.5	0.2	0.16	4.4	9	<0.01
8	09-15-91	920	3.8	62	15.2	0.9	0.41	0.52	8.3	19	0.02
9	09-16-81	700	4.3	17	7.7	3.1	0.14	0.28	5.0	5	<0.01
10	10-02-81	270	4.1	37	33	15.8	0.41	0.94	10.8	30.6	0.02
11	10-23-81	750	4.0	29	9	0.7	0.32	0.18	3.0	5	<0.01
12	10-27-81	470	4.1	12	8.9	0.0	0.16	0.11	1.8	7	<0.01
13	No sample										
14	11-24-81	380	4.4	33	12.0	0.0	0.58	0.39	4.5	11	0.01
15	12-01-81	920	4.2	14	23.6	2.1	0.10	0.01	1.6	<1	<0.01
16	No sample										
17	01-23-82	770	4.3	20	16.4	2.0	0.26	0.20	3.4	4	0.02
18	02-03-82	850	4.6	9	9.2	0.0	0.08	0.08	1.2	1	0.01
19	02-09-82	650	4.3	14	5.1	1.3	0.15	0.22			0.01
20	No sample										
21	03-21-82	800	4.4	10	10.0	0.8	0.80	0.22	2.1	3	0.02
22	03-26-82	265	4.3	17	57.1	8.3	0.25	0.67	6.3	15	0.02

IS = Insufficient sample

Atmospheric Deposition Data
Wetfall Samples Collected at the Strip Commercial (SC) Site

Storm number	Date collected	SO_4 (mg/L)	Cl (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cu (total, µg/L)	Zn (total, µg/L)	Cr (total, µg/L)	Se (total, µg/L)	Hg (total, µg/L)
1	07-02-81	1.7	0.08	0.38	0.05	<0.05	0.05	27	12	3	<1	<0.2
2	08-06-81	3.3	0.5	0.73	0.127	0.35	0.09	15	35	11	<1	24
3	08-08-81	2.9	0.3	0.55	0.095	0.29	0.09	43	14	5	<1	2.3
4	08-12-81	10.0	0.4	0.73	0.091	0.37	0.12	75	36	4	<1	<0.2
5	No sample											
6	08-18-81	10.4	0.4	2.39	0.413	4.61	0.26	143	<5	13	<1	<0.2
7	08-21-81	1.6	0.1	0.39	0.067	0.20	0.10	17	<5	<1	<1	<0.2
8	09-15-81	5.8	0.2	0.45	0.079	0.16	0.08	20	<5	2	<1	<0.2
9	09-16-81	1.6	0.1	0.27	0.055	0.11	0.09	25	13	1	<1	<0.2
10	10-02-81	2.5	0.4	1.29	0.26	1.84	0.16	33	29	2	<1	<0.2
11	10-23-81	2.5	0.40	0.19	0.051	0.49	0.11	9	25	<1		<0.2
12	10-27-81	1.1	<0.1	0.11	0.024	<0.05	0.04	2	18	<1		<0.2
13	No sample											
14	11-24-81	3.0	0.23	0.83	0.044	0.23	0.11	7	18	<1		<0.2
15	12-01-81	1.4	0.19	0.21	0.031	0.29	0.07	8	84	<1		<0.3
16	No sample											
17	01-23-82			0.75	0.11			4	14	5		<0.2
18	02-03-82			0.13	0.04			12	16	<1		<0.2
19	02-09-82			0.34	0.05			506	23	<1		<0.2
20	No sample											
21	03-21-82											
22	03-26-82											

Atmospheric Deposition Data
Wetfall Samples Collected at the Strip Commercial (SC) Site

Storm number	Date collected	Ni (total, µg/L)	Cd (total, µg/L)	Pb (total, µg/L)	Fe (total, µg/L)	Mn (total, µg/L)	Al (total, µg/L)
1	07-02-81	<100	0.3	8	22	<5	
2	08-06-81	<50	3.8	22	80	<5	
3	08-08-81	<50	2.2	14	160	<5	
4	08-12-81	<50	1.3	7	81	<5	
5	No sample						
6	08-18-81	<50	3.0	9	139	<5	
7	08-21-81	<50	0.4	7	56	<5	
8	09-15-81	<50	0.5	14	83	<5	
9	09-16-81	<50	0.6	8	62	<5	
10	10-02-81	<50	0.4	20	514	12	
11	10-23-81		0.4	10	55	<5	<50
12	10-27-81		0.2	8	169	7	<50
13	No sample						
14	11-24-81		0.1	18	76	<5	85
15	12-01-81		0.5	7	136	6	100
16	No sample						
17	01-23-82		0.7	23	140	<5	80
18	02-03-82		0.1	6	53	<5	<50
19	02-09-82		0.4	10	97	<5	60
20	No sample						
21	03-21-82						
22	03-26-82						

Atmospheric Deposition Data
Wetfall Samples Collected at the Residential 1 (R1) Site

Storm number	Date collected	Volume (ml)	pH	Conductivity (μmhos at 25°C)	TDS (mg/L)	TSS (mg/L)	NO_3-N (mg/L)	TKN (mg/L)	TOC (mg/L)	COD (mg/L)	TP (mg/L)
1	07-02-81	500	4.2	20	IS	4	0.16	0.78	9.8	46	<0.01
2	08-06-81	200	4.5	12	<5	<1	1.1	0.29	7.1	23	0.06
3	No sample										
4	No sample										
5	No sample										
6	No sample										
7	08-21-81	460	4.1	26		5.9	0.2	0.07	15	60	0.01
8	09-15-81	710	3.8	63	8.6	0.0	0.34	0.58	5.5	9	0.01
9	09-16-81	635	4.6	9	5.3	0.1	0.07	0.16	6.0	19	<0.01
10	10-02-81	300	4.0	43	36.7	13.3	0.67	0.91	18.2	51	0.02
11	10-23-81	750	4.0	28	8	0.0	0.06	0.26	5.0	6	<0.01
12	10-27-81	650	4.3	7	12.5	0.0	0.08	0.20	1.9	10	<0.01
13	11-20-81	200	4.2	16	28.6	5.7	0.29	0.60	4.5	20	0.01
14	11-24-81	355	4.3	32	11.7	13.6	0.52	0.39	10.1	28	<0.01
15	12-01-81	850	4.2	13	12.8	0.7	0.09	0.08	1.8	2	<0.01
16	01-21-82	830	4.4	20	20.1	0.4	0.13	0.14	2.2	14	<0.01
17	01-23-82	760	4.1	24	14.5	3.8	0.22	0.22	2.5	33	<0.01
18	02-03-82	975	4.5	9	7.8	0.7	0.07	0.08	3.4	4	<0.01
19	02-09-82	725	3.9	23	8.5	1.7	0.18	0.44			0.02
20	No sample										
21	03-21-82	715	4.5	7	5.6	0.7	0.08	0.24	11.0	4	0.05
22	No sample										
23	No sample										

IS = Insufficient sample

Atmospheric Deposition Data
Wetfall Samples Collected at the Residential 1 (R1) Site

Storm number	Date collected	SO_4 (mg/L)	Cl (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cu (total, µg/L)	Zn (total, µg/L)	Cr (total, µg/L)	Se (total, µg/L)	Hg (total, µg/L)
1	07-02-81	2.0	<0.1	0.30	0.04	<0.05	0.04	90	24	4	<1	<0.2
2	08-06-81	4.0	0.9	1.17	0.183	0.77	0.17	94	63	23	<1	<4.6
3	No sample											
4	No sample											
5	No sample											
6	No Sample											
7	08-21-81	1.8	0.01	0.41	0.078	0.09	0.11	18	24	29	1	<0.2
8	09-15-81	5.0	0.2	0.61	0.107	0.12	0.09	38	<5	1	<1	<2.6
9	09-16-81	0.8	0.1	0.41	0.067	<0.05	0.07	24	<5	3	<1	<0.2
10	10-02-81	6.0	0.33	2.07	0.29	0.36	0.20	53	25	4	<1	<0.2
11	10-23-81	0.4	0.4	0.37	0.053	0.31	0.08	6	36	1		<0.2
12	10-27-81	1.1	0.2	0.38	0.034	0.50	0.24	14	76	<1		<0.2
13	11-20-81	3.7	0.54	64.00	0.509	1.00	0.40	29	51	<1		<0.2
14	11-24-81	3.3	0.18	0.35	0.047	0.18	0.12	20	42	<1		<0.2
15	12-01-81	1.7	0.23	0.38	0.047	0.17	0.04	11	46	<1		<0.2
16	01-21-82			0.19	0.05			11	27	<1		<0.2
17	01-23-82			0.66	0.11			13	35	4		<0.2
18	02-03-82			0.25	0.04			12	13	<1		<0.2
19	02-09-82			0.18	0.03			170	27	<1		<0.2
20	No sample											
21	03-21-82											
22	No sample											
23	No sample											

Atmospheric Deposition Data
Wetfall Samples Collected at the Residential 1 (R1) Site

Storm number	Date collected	Ni (total, µg/L)	Cd (total, µg/L)	Pb (total, µg/L)	Fe (total, µg/L)	Mn (total, µg/L)	Al (total, µg/L)
1	07-02-81	<100	0.6	8	52	<5	
2	08-06-81	<50	3.1	17	143	<5	
3	No sample						
4	No sample						
5	No sample						
6	No sample						
7	08-21-81	<50	6.9	13	114	<5	
8	09-15-81	<50	0.5	15	80	<5	
9	09-16-81	<50	0.7	12	63	<5	
10	10-02-81	<50	0.4	25	673	11	
11	10-23-81		3.0	11	174	<5	<50
12	10-27-81		0.6	14	110	7	70
13	11-20-81		0.6	49	254	<5	371
14	11-24-81		0.5	20	158	<5	<50
15	12-01-81		0.2	9	106	9	90
16	01-21-82		1.0	15	160	<5	<50
17	01-23-82		0.5	22	170	9	90
18	02-03-82		0.2	8	58	<5	<50
19	02-09-82		0.2	8	73	12	70
20	No sample						
21	03-21-82						
22	No sample						
23	No sample						

Atmospheric Deposition Data
Wetfall Samples Collected at the Residential 2 (R2) Site

Storm number	Date collected	Volume (ml)	pH	Conductivity (μmhos at 25°C)	TDS (mg/L)	TSS (mg/L)	NO_3-N (mg/L)	TKN (mg/L)	TOC (mg/L)	COD (mg/L)	TP (mg/L)
1	07-02-81	600	4.2	24	IS	47	0.13	0.20	2.7	7	0.008
2	08-06-81	300	4.3	16	<5	<1	0.9	0.22	11.3	38	0.02
3	No sample										
4	08-12-81	400	3.8	66	22.5	5.0	2.5	0.53	7.7	59	0.01
5	No sample										
6	No sample										
7	08-21-81	1080	4.1	26	9.0	<0.5	0.2	0.16	2.8	5	<0.01
8	09-15-81	925	3.8	63	17.3	2.4	0.34	0.41	4.9	16	0.02
9	09-16-81	700	5.4	8	0.0	5.1	0.19	0.20	3.3	7	<0.01
10	10-02-81	250	4.0	43	44.0	8.0	0.52	0.89	11.3	27	0.02
11	10-23-81	745	4.0	28	16	0.0	0.34	0.20	2.6	12	<0.01
12	10-27-81	475	4.1	12	6.5	0.0	0.16	0.60	2.8	11	0.23
13	No sample										
14	11-24-81	360	4.0	32	13.4	0.3	0.51	0.25	3.3	6	<0.01
15	12-01-81	940	4.3	11	11.6	2.0	0.09	0.09	2.1	3	<0.01
16	No sample										
17	01-12-82	750	3.9	29	16.1	0.1	0.23	0.34	4.8	8	0.02
18	02-03-82	850	4.6	8	7.4	1.5	0.08	0.10	5.5	11	0.01
19	02-09-82	700	4.0	22	8.4	0.9	0.15	0.20			0.01
20	No sample										
21	03-21-82	780	4.3	8	11.4	0.9	0.13	0.20	10.0	21	0.02
22	03-26-82	235	4.1	21	85.2	10.0	0.26	0.55	6.2	14	0.02

IS = Insufficient sample

Atmospheric Deposition Data
Wetfall Samples Collected at the Residential 2 (R2) Site

Storm number	Date collected	SO_4 (mg/L)	Cl (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cu (total, µg/L)	Zn (total, µg/L)	Cr (total, µg/L)	Se (total, µg/L)	Hg (total, µg/L)
1	07-02-81	1.7	0.08	0.23	0.03	<0.05	0.07	30	13	2	<1	<0.2
2	08-06-81	2.5	0.5	0.51	0.075	1.40	0.09	76	38	16	<1	<2.2
3	No sample											
4	08-12-81	9.2	0.4	0.99	0.104	0.20	0.16	49	55	4	<1	<0.2
5	No sample											
6	No sample											
7	08-21-81	1.4	0.1	0.33	0.051	0.24	0.06	25	<5	<1	1	0.2
8	09-15-81	5.0	0.2	0.46	0.097	0.10	0.08	14	<5	2	<1	<0.2
9	09-16-81	1.8	0.2	1.34	0.188	0.13	0.12	50	<5	1	<1	<0.2
10	10-02-81	5.6	0.20	1.42	0.16	0.44	0.18	182	338	13	<1	<0.2
11	10-23-81	2.5	0.5	0.10	0.049	0.31	0.06	13	24	1		<0.2
12	10-27-81	1.1	0.1	0.11	0.028	0.13	0.09	6	31	<1		<0.2
13	No sample											
14	11-24-81	3.0	<0.1	0.18	0.031	0.19	0.06	<1	19	<1		1.6
15	12-01-81	1.5	0.22	0.13	0.033	0.18	0.03	2	29	2		<0.2
16	No sample											
17	01-12-82			0.25	0.05			23	9	<1		<0.2
18	02-12-82			0.28	0.05			13	20	<1		<0.2
19	02-09-82			0.20	0.03			260	41	<1		<0.2
20	No sample											
21	03-21-82											
22	03-26-82											

Atmospheric Deposition Data
Wetfall Samples Collected at the Residential 2 (R2) Site

Storm number	Date collected	Ni (total, µg/L)	Cd (total, µg/L)	Pb (total, µg/L)	Fe (total, µg/L)	Mn (total, µg/L)	Al (total, µg/L)
1	07-02-81	<100	0.3	10	275	<5	
2	08-06-81	<50	5.5	4	53	<5	
3	No sample						
4	08-12-81	<50	0.5	16	88	<5	
5	No sample						
6	No sample						
7	08-21-81	<50	0.1	4	43	<5	
8	09-15-81	<50	0.5	32	142	<5	
9	09-16-81	<50	2.1	13	122	11	
10	10-02-81	<50	0.4	13	220	<5	
11	10-23-81		0.1	11	44	<5	50
12	10-27-81		1.7	9	232	7	56
13	No sample						
14	11-24-81		0.4	18	51	<5	<50
15	12-01-81		0.1	6	33	<5	<50
16	No sample						
17	01-12-82		0.3	13	94	<5	80
18	02-03-82		0.2	8	64	5	<50
19	02-09-82		0.3	7	49	<5	<50
20	No sample						
21	03-21-82						
22	No sample						

Atmospheric Deposition Data[a]
Dryfall Samples Collected at the Central Business District (CBD) Site

Storm number	Date collected	Dilution volume (ml)	TKN (mg/bucket)	TP (mg/bucket)	NO_2+NO_3-N (mg/bucket)	TOC (mg/bucket)	COD (mg/bucket)	K (mg/bucket)	Ca (mg/bucket)	Mg (mg/bucket)	Na (mg/bucket)	SO_4 (mg/bucket)
1	07-02-81	500	0.12	<0.005	0.08	1.2	5	0.06	1.3	0.17	<0.02	0.3
2	08-06-81	500	0.08	0.01	0.03	1.6	6	0.03	0.93	0.12	0.30	0.1
3	No sample											
4	No sample											
5	08-16-81	500	0.02	0.01	0.04	1.5	7	0.03	0.75	0.08	0.14	0.25
6	08-18-81	500	0.09	<0.005	0.04	1.3	2	0.02	0.30	0.04	0.07	0.35
7	08-21-81	500	0.08	0.005	0.04	1.0	3	0.02	0.66	0.08	<0.03	0.20
8	09-15-81	500	0.07	0.02	0.07	2.2	10	0.08	1.94	0.221	0.06	0.9
9	09-16-81	500	0.06	<0.005	0.02	1.6	2	0.04	0.36	0.066	<0.03	0.2
10	10-02-81	500	0.16	0.02	0.14	8.0	26	0.18	5.5	0.82	0.10	1.8
11	10-23-81	500	0.11	0.16	0.04	1.4	4	0.02	0.47	0.08	0.09	0.3
12	10-27-81	500	0.08	0.0005	<0.005	0.6	4	0.04	0.21	0.034	0.03	0.05
Nov[b]	12-01-81	500	0.19	0.025	0.27	3.2	27	0.24	5.25	0.755	0.19	5.0
Dec	01-05-82	500	0.23	0.04	0.6	5.0	55	0.27	5.00	0.70	0.85	4.6
Jan	02-02-82	500	0.18	0.03	0.34	3.6	28		5.50	0.70		
Feb	03-02-82		0.13	0.035	0.38	3.2	28		7.00	0.90		
Mar	04-06-82	500	0.21	0.26	0.18	5.5	IS					

a. All data is stored on STORET as mg of constituent/kg of total solids.

b. All data collected after this date is representative of monthly dryfall sample collection.

IS = Insufficient sample.

Atmospheric Deposition Data[a]
Dryfall Samples Collected at the Central Business District (CBD) Site

Storm number	Date collected	Cl (mg/bucket)	Total solids (mg/bucket)	Fe, total (µg/bucket)	Mn, total (µg/bucket)	Cu, total (µg/bucket)	Zn, total (µg/bucket)	Cr, total (µg/bucket)	Se, total (µg/bucket)
1	07-02-81	<0.02		90	5	7	22	6	<1
2	08-06-81	0.10		51	<3	23	11	8	<0.5
3	No sample								
4	No sample								
5	08-16-81	<0.05		15	<3	6	3	0.5	<0.5
6	08-18-81	0.05		10	<3	2	<3	<0.5	<0.5
7	08-21-81	<0.05	4	44	<3	<5	4	<0.5	0.5
8	09-15-81	0.1	6.9	244	8	12	52	1	<0.5
9	09-16-81	0.1	0.0	67	3	16	<3	1	<0.5
10	10-02-81	0.1	23	810	28	14	76	1	<0.5
11	10-23-81	0.05	3.7	93	<3	1	108	5	
12	10-27-81	<0.05	12.2	60	4	1	10	<0.5	
Nov[b]	12-01-81	0.5	26.0	1145	56	12	141	3	
Dec	01-05-82	2.15		1450	70	24	120	3	
Jan	02-02-82			1150	55	17	115	0.5	
Feb	03-02-82		60.0	1150	15	40	145	1	
Mar	04-06-82		100						

a. All data is stored on STORET as mg of constituent/kg of total solids.

b. All data collected after this date is representative of monthly dryfall sample collection.

IS = Insufficient sample.

Atmospheric Deposition Data[a]
Dryfall Samples Collected at the Central Business District (CBD) Site

Storm number	Date collected	Hg, total (µg/bucket)	Ni, total (µg/bucket)	Cd, total (µg/bucket)	Pb, total (µg/bucket)	Al, total (µg/bucket)
1	07-02-81	0.3	<50	0.4	14	
2	08-06-81	2.8	<25	0.4	4	
3	No sample					
4	No sample					
5	08-16-81	<0.1	<25	0.1	<0.5	
6	08-18-81	<0.1	<25	0.3	<0.5	
7	08-21-81	0.4	<25	0.1	4	
8	09-15-81	<0.1	<25	0.3	18	
9	09-16-81	<0.1	<25	0.2	11	
10	10-02-81	<0.1	<25	0.3	47	
11	10-23-81	<0.1		<0.05	15	40
12	10-27-81	<0.1		<0.05	6	45
Nov[b]	12-01-81	0.3		0.6	165	640
Dec	01-05-82	<0.1		2.75	80	600
Jan	02-02-82	<0.2		0.15	50	750
Feb	03-02-82	<0.1		0.4	125	700
Mar	04-06-82					

a. All data is stored on STORET as mg of constituent/kg of total solids.

b. All data collected after this date is representative of monthly dryfall sample collection.

IS = Insufficient sample.

Atmospheric Deposition Data[a]
Dryfall Samples Collected at the Strip Commercial (SC) Site

Storm number	Date collected	Dilution volume (ml)	TKN (mg/bucket)	TP (mg/bucket)	NO_2+NO_3-N (mg/bucket)	TOC (mg/bucket)	COD (mg/bucket)	K (mg/bucket)	Ca (mg/bucket)	Mg (mg/bucket)	Na (mg/bucket)	SO_4 (mg/bucket)
1	07-02-81	500	0.12	0.02	0.04	2.4	8.5	0.38	0.73	0.17	<0.02	0.2
2	08-06-81	500	0.07	0.01	0.05	1.0	7	0.03	0.76	0.08	0.27	0.15
3	08-08-81	500	0.13	0.01	0.02	1.8	6	0.03	0.22	0.03	0.30	0.1
4	08-12-81	500	0.02	0.005	0.25	0.9	6	0.04	0.73	0.77	0.28	0.25
5	No sample											
6	08-18-81	500	0.20	<0.005	0.04	1.2	4	0.02	0.22	0.04	0.09	0.35
7	08-21-81	500	0.27	0.08	0.04	2.2	4	0.04	0.46	0.12	0.09	0.15
8	09-15-81	500	0.07	0.005	0.07	6.0	19	0.06	1.33	0.276	0.08	0.35
9	09-16-81	500	0.07	0.005	0.03	3.0	34	0.07	0.49	0.77	<0.03	0.35
10	10-02-81	500	0.13	0.02	0.17	3.0	8	0.18	4.11	0.88	0.15	1.4
11	10-23-81	500	0.06	0.005	0.01	2.2	4	0.09	0.84	0.08	0.09	0.2
12	10-27-81	500	0.05	0.005	0.01	0.6	3	0.06	0.29	0.054	0.05	0.05
Nov[b]	12-01-81	500	0.11	0.015	0.22	2.6	15	0.23	5.2	1.11	0.13	4.05
Dec	No sample											
Jan	02-02-82	500				2.2	17					
Feb	03-02-82	500	0.90	0.025	0.32	3.2	22		4.55	0.70		
Mar	04-06-82	500	1.85	0.295	5.50	8.5	IS					

a. All data is stored on STORET as mg of constituent/kg of total solids.

b. All data collected after this date is representative of monthly dryfall sample collection.

IS = Insufficient sample.

Atmospheric Deposition Data[a]
Dryfall Samples Collected at the Strip Commercial (SC) Site

Storm number	Date collected	Cl (mg/bucket)	Total solids (mg/bucket)	Fe, total (μg/bucket)	Mn, total (μg/bucket)	Cu, total (μg/bucket)	Zn, total (μg/bucket)	Cr, total (μg/bucket)	Se, total (μg/bucket)
1	07-02-81	<0.05		37	5	14	14	2	<0.5
2	08-06-81	0.1		65	<3	8	8	4	<0.5
3	08-08-81	0.15		11	<3	14	4	1	<0.5
4	08-12-81	0.15		61	<3	12	12	0.5	<0.5
5	No sample								
6	08-18-81	0.05		16	<3	<0.5	<3	2	<0.5
7	08-21-81	<0.05	8	44	<3	20	4	0.5	0.5
8	09-15-81	<0.05	7.4	172	10	13	20	1	<0.5
9	09-16-81	0.05	0.0	84	3	17	<3	9	<0.5
10	10-02-81	0.15	26	750	33	7	75	<0.5	<0.5
11	10-23-81	<0.05	4.2	77	<3	2	24	1	
12	10-27-81	0.05	15.5	101	5	3	10	<0.5	
Nov[b]	12-01-81	0.21	17.4	855	58	6	95	4	
Dec	No sample								
Jan	02-02-82								
Feb	03-02-82		32	350	37	105	48	0.5	
Mar	04-06-82		80						

a. All data is stored on STORET as mg of constituent/kg of total solids.

b. All data collected after this date is representative of monthly dryfall sample collection.

IS = Insufficient sample.

Atmospheric Deposition Data[a]
Dryfall Samples Collected at the Strip Commercial (SC) Site

Storm number	Date collected	Hg, total (μg/bucket)	Ni, total (μg/bucket)	Cd, total (μg/bucket)	Pb, total (μg/bucket)	Al, total (μg/bucket)
1	07-02-81	<0.2	<50	0.2	12	
2	08-06-81	2.0	<25	0.3	9	
3	08-08-81	3.8	<25	0.3	<0.5	
4	08-12-81	<0.1	<25	0.2	10	
5	No sample					
6	08-18-81	<0.1	<25	0.1	1	
7	08-21-81	<0.1	<25	0.1	2	
8	09-15-81	1.3	<25	0.2		
9	09-16-81	<0.1	<25	0.2	16	
10	10-02-81	<0.1	<25	0.6	50	
11	10-23-81	<0.1		<0.05	10	55
12	10-27-81	<0.1		0.9	5	55
Nov[b]	12-01-81	0.2		0.3	145	445
Dec	No sample					
Jan	02-02-82					
Feb	03-02-82	<0.2		0.25	75	220
Mar	04-06-82					

a. All data is stored on STORET as mg of constituent/kg of total solids.

b. All data collected after this date is representative of monthly dryfall sample collection.

IS = Insufficient sample.

Atmospheric Deposition Data[a]
Dryfall Samples Collected at the Residential 1 (R1) Site

Storm number	Date collected	Dilution volume (ml)	TKN (mg/bucket)	TP (mg/bucket)	NO_2+NO_3-N (mg/bucket)	TOC (mg/bucket)	COD (mg/bucket)	K (mg/bucket)	Ca (mg/bucket)	Mg (mg/bucket)	Na (mg/bucket)	SO_4 (mg/bucket)
1	No sample											
2	No sample											
3	No sample											
4	No sample											
5	No sample											
6	No sample											
7	08-21-81	500	0.08	0.005	0.04	1.6	4	0.04	0.32	0.05	0.14	0.2
8	09-15-81	500	0.06	0.01	0.04	2.2	6	0.06	1.24	0.150	0.04	0.35
9	09-16-81	500	0.06	<0.005	<0.02	3.0	19	0.04	0.26	0.047	0.05	0.15
10	10-02-81	500	0.10	0.02	0.14	4.4	12	0.18	3.18	0.328	0.10	1.0
11	10-23-81	500	0.02	<0.005	0.02	2.0	3	0.05	0.34	0.047	0.09	0.2
12	10-27-81	500	0.08	<0.005	0.01	1.7	6	0.04	0.12	0.019	0.04	0.2
Nov[b]	12-01-81	500	0.12	0.025	0.18	3.2	14	0.16	4.30	0.433	0.10	4.5
Dec	No sample											
Jan	02-02-82	500				2.8	15					
Feb	03-02-82	500	0.09	0.015	0.25	4.0	17		2.6	0.335		
Mar	04-06-82	500	0.27	0.08	0.12	5.0	IS					

a. All data is stored on STORET as mg of constituent/kg of total solids.

b. All data collected after this date is representative of monthly dryfall sample collection.

IS = Insufficient sample.

Atmospheric Deposition Data[a]
Dryfall Samples Collected at the Residential 1 (R1) Site

Storm number	Date collected	Cl (mg/bucket)	Total solids (mg/bucket)	Fe, total (µg/bucket)	Mn, total (µg/bucket)	Cu, total (µg/bucket)	Zn, total (µg/bucket)	Cr, total (µg/bucket)	Se, total (µg/bucket)
1	No sample								
2	No sample								
3	No sample								
4	No sample								
5	No sample								
6	No sample								
7	08-21-81	<0.05	6	32	<3	10	<3	2	0.5
8	09-15-81	0.05	13	184	8	12	5	1	<0.5
9	09-16-81	0.05	0.4	42	<3	13	<3	2	<0.5
10	10-02-81	0.05	19	630	25	20	42	1.5	<0.5
11	10-23-81	<0.05	6.2	127	<3	4	36	2	
12	10-27-81	0.1	3.8	41	6	4	13	<0.5	
Nov[b]	12-01-81	0.18	15.6	740	34	9	86	1.5	
Dec	No sample								
Jan	02-02-82								
Feb	03-02-82		22.0	315	29	80	65	<0.5	
Mar	04-06-82		37.5						

a. All data is stored on STORET AS mg of constituent/kg of total solids.

b. All data collected after this date is representative of monthly dryfall sample collection.

IS = Insufficient sample.

Atmospheric Deposition Data[a]
Dryfall Samples Collected at the Residential 1 (R1) Site

Storm number	Date collected	Hg, total (µg/bucket)	Ni, total (µg/bucket)	Cd, total (µg/bucket)	Pb, total (µg/bucket)	Al, total (µg/bucket)
1	No sample					
2	No sample					
3	No sample					
4	No sample					
5	No sample					
6	No sample					
7	08-21-81	4.7	<25	0.5	4	
8	09-15-81	<0.1	<25	0.2	12	
9	09-16-81	<0.1	<25	<0.05	185	
10	10-02-81	<0.1	<25	0.2	26	100
11	10-23-81	0.4		0.1	7	50
12	10-27-81	<0.1		0.05	5	25
Nov[b]	12-01-81	0.1		0.45	85	355
Dec	No sample					
Jan	02-02-82					
Feb	03-02-82	<0.1		0.6	41	175
Mar	04-06-82					

a. All data is stored on STORET as mg of constituent/kg of total solids.

b. All data collected after this date is representative of monthly dryfall sample collection.

IS = Insufficient sample.

Atmospheric Deposition Data[a]
Dryfall Samples Collected at the Residential 2 (R2) Site

Storm number	Date collected	Dilution volume (ml)	TKN (mg/bucket)	TP (mg/bucket)	NO_2+NO_3-N (mg/bucket)	TOC (mg/bucket)	COD (mg/bucket)	K (mg/bucket)	Ca (mg/bucket)	Mg (mg/bucket)	Na (mg/bucket)	SO_4 (mg/bucket)
1	07-02-81	500	0.9	0.12	0.06	2.0	7.5	0.95	0.27	0.06	<0.02	0.2
2	08-06-81	500	0.8	0.16	0.10	3.7	26	1.2	0.36	0.09	0.63	0.25
3	No sample											
4	08-12-81	500	0.06	0.005	0.10	1.4	5	0.03	0.35	0.04	0.32	0.15
5	No sample											
6	No sample											
7	08-21-81	500	0.04	0.005	0.02	1.2	2	0.04	0.14	0.02	0.04	0.15
8	09-15-81	500	0.55	0.24	0.06	2.6	5	0.28	0.32	0.128	0.11	0.35
9	09-16-81	500	0.08	<0.005	<0.02	2.4	6	0.08	0.14	0.030	0.08	0.15
10	10-02-81	500	1.2	0.18	0.14	14	36	0.04	0.86	0.243	0.15	1.2
11	10-23-81	500	0.01	<0.005	0.14	1.2	5	0.02	0.11	0.022	0.15	1.2
12	10-27-81	500	0.25	0.10	0.01	1.0	4	0.02	0.07	0.011	0.11	0.05
Nov[b]	12-01-81	500	0.05	<0.005	0.11	1.0	3	0.09	0.68	0.091	0.09	1.0
Dec	No sample											
Jan	02-02-82	500				465	1200					
Feb	03-02-82	500	0.08	0.01	0.13	1.5	5		0.75	0.11		
Mar	04-06-82	500	0.15	0.04	0.21	3.5	IS					

a. All data is stored on STORET as mg of constituent/kg of total solids.

b. All data collected after this date is representative of monthly dryfall sample collection.

IS = Insufficient sample.

Atmospheric Deposition Data[a]
Dryfall Samples Collected at the Residential 2 (R2) Site

Storm number	Date collected	Cl (mg/bucket)	Total solids (mg/bucket)	Fe, total (μg/bucket)	Mn, total (μg/bucket)	Cu, total (μg/bucket)	Zn, total (μg/bucket)	Cr, total (μg/bucket)	Se, total (μg/bucket)
1	07-02-81	0.1		32	<2	4	11	4	<1
2	08-06-81	0.15		44	<3	29	6	2	<0.5
3	No sample								
4	08-12-81	0.15		106	8	12	8	4	<0.5
5	No sample								
6	No sample								
7	08-21-81	<0.05	3	31	<3	6	<3	1	0.5
8	09-15-81	0.1	12	85	3	8	<3	1	<0.5
9	09-16-81	0.15	0.0	41	<3	10	<3	1	<0.5
10	10-02-81	0.15	26	144	10	19	28	<0.5	<0.5
11	10-23-81	0.2	5.0	34	<3	6	20	1	
12	10-27-81	<0.05	7.6	303	6	11	23	<0.5	
Nov[b]	12-01-81	0.08	2.9	126	7	<0.5	22	2	
Dec	No sample								
Jan	02-02-82								
Feb	03-02-82		10.0	103	11	10	18	<0.5	
Mar	04-06-82		26.5						

a. All data is stored on STORET as mg of constituent/kg of total solids.

b. All data collected after this date is representative of monthly dryfall sample collection.

IS = Insufficient sample.

Atmospheric Deposition Data[a]
Dryfall Samples Collected at the Residential 2 (R2) Site

Storm number	Date collected	Hg, total (µg/bucket)	Ni, total (µg/bucket)	Cd, total (µg/bucket)	Pb, total (µg/bucket)	Al, total (µg/bucket)
1	07-02-81	0.3	<50	0.20	4	
2	08-06-81	5.5	<25	0.40	2	
3	No sample					
4	08-12-81	<0.1	<25	0.05	6	
5	No sample					
6	No sample					
7	08-21-81	<0.1	<25	0.05	2	
8	09-15-81	<0.1	<25	0.20	6	
9	09-16-81	<0.1	<25	6.00	2	
10	10-02-81	<0.1	<25	0.30	6	
11	10-23-81	<0.01		<0.05	4	55
12	10-27-81	<0.1		0.20	2	<25
Nov[b]	12-01-81	0.1		0.05	18	80
Dec	No sample					
Jan	02-02-82					
Feb	03-02-82	<0.1		0.10	17	70
Mar	04-06-82					

a. All data is stored on STORET as mg of constituent/kg of total solids.

b. All data collected after this date is representative of monthly dryfall sample collection.

IS = Insufficient sample.

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